Draft Recovery Plan

for Coastal Plants of the

Northern San Francisco Peninsula

Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

Approved: XXXXXXXXXXXXXXXXXXXXXXXX
Manager, California/Nevada Operations Office,
Region 1, U.S. Fish and Wildlife Service

Date: ________________________________

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Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. We, the U.S. Fish and Wildlife Service, publish recovery plans, sometimes preparing them with the assistance of recovery teams, contractors, State agencies, and others. Objectives of the plan will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific tasks and may not represent the views or official positions or approval of any individuals or agencies involved in the recovery plan other than our own. They represent our official position **only** after they have been signed by the Director, Regional Director, or Manager as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

Literature Citation Should Read As Follows:

U.S. Fish and Wildlife Service. 2001. Draft Recovery Plan for Coastal Plants of the Northern San Francisco Peninsula. U.S. Fish and Wildlife Service, Portland, Oregon, xv + 253 pp.

ACKNOWLEDGMENTS

This draft recovery plan was prepared by Peter Baye of the Sacramento Fish and Wildlife Office, and edited by Karen Miller and Diane Elam.

Marc Albert and Sharon Farrell of the Golden Gate National Recreation Area (National Park Service) provided valuable information and insights on the past and prospective vegetation management of the Presidio and Fort Funston, as well as unpublished data on San Francisco lessingia and Raven's manzanita. Joe Cannon and Marc Albert of the Golden Gate National Recreation Area contributed detailed site-specific information on the management and restoration of remnant dunes supporting San Francisco lessingia. Adam Whelchel of San Francisco State University contributed original unpublished data on the insect visitors of San Francisco lessingia. Staci Markos of the University of California at Berkeley contributed insights on the taxonomy of San Francisco lessingia. Mike Vasey of San Francisco State University made available new data and analysis prepared with co-authors Staci Markos, Lena Hileman, and Tom Parker (unpublished at the time earlier drafts of this recovery plan were prepared) on the taxonomy of Raven's manzanita. Susan Smith of San Francisco provided information and guidance on the history and future of San Francisco lessingia's conservation, as well as unpublished notes on plant community composition of lessingia sites. We also acknowledge the valuable recent scientific contributions of Yolanda Mollette and Crima Pogge, for their studies of San Francisco dune seed banks and lessingia population ecology, respectively. Sylvia Martin of the U.S. Fish and Wildlife Service graciously assisted preparation of photographic reproductions.

EXECUTIVE SUMMARY

Current Species Status: This recovery plan features two federally endangered plant species endemic to the northern San Francisco peninsula. San Francisco lessingia (*Lessingia germanorum*), an annual herb in the aster family, exists at six sites in the Presidio of San Francisco and one site in Daly City. It is threatened by invasion of nonnative vegetation, habitat loss, and potential land use conflicts in limited restorable urban habitat. Raven's manzanita (*Arctostaphylos hookeri* ssp. *ravenii*) is a rare evergreen creeping shrub in the heath family. Only one genetic individual exists in the wild, but some clones of the original and some of its seedlings have been artificially propagated. The original plant is located in remnant coastal scrub and grassland in the Presidio, along with its transplanted clones. It is threatened by failure to reproduce naturally, habitat loss, potential land use conflicts in limited restorable urban habitat, and disease.

Geographic and Ecological Scope of the Recovery Plan: The ecosystems on which the endangered species of this recovery plan depend are limited to narrow geographic areas of the northern San Francisco peninsula. Their habitats are further restricted to specific substrate types: old coastal sand deposits (San Francisco lessingia) and outcrops of serpentine or similar rocks (Raven's manzanita). Both taxa grow only in sparse, relatively open native coastal scrub and grassland vegetation.

Taxonomic Scope of the Recovery Plan: This recovery plan serves as a draft revision for the Raven's Manzanita Recovery Plan (U.S. Fish and Wildlife Service 1984), addressing Raven's manzanita jointly with San Francisco lessingia to facilitate a more holistic ecosystem-based approach for these species. This recovery plan considers actions for the two featured endangered species along with conservation needs of a number of plants and animals that are associated with them. Several other associated federally-listed taxa that are already covered by other recovery plans are discussed herein: bay checkerspot butterfly (*Euphydryas editha bayensis*), Marin dwarf-flax (*Hesperolinon congestum*), and Presidio clarkia (*Clarkia franciscana*), covered by the Recovery Plan for Serpentine Soil Species of the San Francisco Bay area (U.S. Fish and Wildlife Service 1998*a*); and Myrtle's silverspot butterfly (*Speyeria zerene myrtleae*) and beach layia (*Layia carnosa*), covered by the Recovery Plan for Seven Coastal Plants and the Myrtle's Silverspot Butterfly (U.S. Fish and Wildlife Service 1998*b*). In addition, the recovery plan considers 16 plant species of concern associated with San Francisco lessingia and Raven's manzanita. These 16 species are uncommon to rare plants known to be at risk of either range collapse (local or regional extinction) or extinction. Seventeen other plant species of local or regional conservation significance are also considered. These plants share habitats with the listed species and have suffered substantial declines on the northern San Francisco Peninsula and adjacent coast.

Recovery Priority: San Francisco lessingia: 2C (full species; high threats; high recovery potential; conflict with development projects)

Raven's manzanita: 12 (subspecies; moderate threats; low recovery potential)

Recovery priority numbers are based on criteria published by *Federal Register* Notice (48 FR 43098; September 21, 1983).

Recovery Objectives: The objectives of this recovery plan are to conserve and restore sufficient habitat and populations of San Francisco lessingia and Raven's manzanita to warrant their reclassification from endangered to threatened, and ultimately to delist San Francisco lessingia. Recovery of Raven's manzanita sufficient to warrant delisting is not projected for the foreseeable future.

Actions Needed: This recovery plan does not focus on actions that only benefit managed populations of the two listed taxa featured in this plan. Instead it stresses re-establishing dynamic, persistent populations of the listed taxa within plant communities that have been restored to be as "self-sustaining" as possible within urban wildland reserves. Recovery actions for San Francisco lessingia focus on the restoration and management of large, dynamic mosaics of coastal dune areas supporting shifting populations within the species' narrow historic range. Recovery of Raven's manzanita will include, but will not be limited to, the original recovery strategy presented in the Raven's Manzanita Recovery Plan

(U.S. Fish and Wildlife Service 1984). This strategy emphasized the stabilization of the single remaining genetic individual, which is necessary but without further measures would result in a dead end to the species' evolution. This recovery plan seeks to re-establish multiple sexually reproducing populations of Raven's manzanita in association with historically associated species of local serpentine outcrops.

Specific actions needed include:

1. Protect and restore a series of ecological urban wildland reserves.

2. Promote population increases of target species within urban wildland reserves and reintroduce target species to restored habitat.

3. Long-term removal (local eradication) or suppression of invasive, nonnative vegetation within and around all reserves and reestablishment of native communities compatible with endangered species within the ecological reserves.

Recovery actions will occur in three identified recovery units for San Francisco lessingia including: 1) the Presidio of San Francisco (National Park Service and Presidio Trust lands); 2) Fort Funston (National Park Service lands) and Daly City (City of Daly City); and 3) the satellite reserves, which are smaller urban park dune remnants (City of San Francisco). Actions for Raven's manzanita will occur in serpentine bedrock and soil outcrops of the Presidio, mostly along bluffs of the north shore, and on hilltop bedrock outcrops at selected locations within San Francisco (city and some Federal lands).

Recovery Criteria:

San Francisco lessingia will be considered for downlisting to threatened status when interim recovery criteria are met, a reintroduced population at Fort Funston has persisted over a full precipitation cycle, and the Lobos Dunes unit has expanded to Battery Caulfield Road and upper Baker Beach. The species will be considered for delisting when long-term recovery criteria are met.

Interim Recovery Criteria

1) Long-term expansion of existing populations and reduction of nonnative vegetation occurs in dune reserves in the Presidio Recovery Unit (Lobos Creek, Battery Caulfield, Wherry, Rob Hill, and Marine Hospital sites). The populations in these reserves are expected to fluctuate but should not decline below 50,000, 1,000, 5,000, 5,000, and 5,000, respectively. Cover of nonnative vegetation in these reserves should be less than 5 percent, 20 percent, 5 percent, 20 percent, and 20 percent, respectively.

2) The population of the Daly City reserve shows no net long-term decrease. Populations are expected to fluctuate but should not decline below 50,000 plants. Cover of nonnative vegetation should show no progressive increase over more than two years.

3) At least 500 seeds representing both the existing Presidio and Daly City populations are stored and maintained in qualified botanical gardens as insurance against extinction in the wild.

Long-term Recovery Criteria

All reserves must be protected in perpetuity with appropriate vegetation management.

1) Expanded, restored reserves with natural vegetation and dune dynamics are established in the Presidio Recovery Unit. The area including Baker Beach dunes, Lobos Dunes and nearby conifer groves, Wherry Dunes and Housing sites, and the Battery Caulfield Road site must be restored to a contiguous dune field with unobstructed wind fetch to the Golden Gate, locally steep dune slopes, and a natural successional mosaic of active and stabilizing dune blowouts (population at least 500,000 plants; nonnative vegetation cover must not exceed 5 percent during first 10 years of restoration and must decline over first 15 years). Dune habitat at the Rob Hill reserve area must increase to 2 hectares (5 acres) and the southwest slope of Rob Hill must be restored to dune scrub (population at least 100,000 plants; nonnative vegetation cover must not exceed 5 percent).

At least 3 hectares (7 acres) of the Marine Hospital dune slope must be restored to native dune vegetation (population at least 50,000 plants; nonnative vegetation cover must not exceed 5 percent).

2) At least 1.2 hectares (3 acres) of Daly City Reserve are cleared of nonnative vegetation and intensively managed (population at least 50,000 plants; no increases in nonnative vegetation).

3) Dune restoration and vegetation management must be done on 30 hectares (75 acres) at Fort Funston Reserve. A population should be reintroduced from the Daly City seed source (population at least 10,000 plants after 5 years; must reach 500,000 plants after 10 years; new colonies must spontaneously establish within 10 years). Nonnative woody vegetation cover must be below 1 percent; iceplant and European beachgrass cover must decline and be below 10 percent after 10 years.

4) Populations must be introduced in the Satellite Recovery Unit (should reach 100,000 plants within 10 years, with minimum size of 5,000 plants). This criterion is preliminary subject to additional information.

Raven's manzanita will be considered for downlisting to threatened when interim recovery criteria are met, five spontaneously reproducing variable populations are established in reserves in San Francisco outside the Presidio, two sexually reproduced generations are established within the Presidio, and population size and individual clone size increase at all sites over 30 years.

Interim Recovery Criteria

1) The original site of the remnant clone and the sites of its daughter clones are maintained and protected in perpetuity. All clones in the wild must increase in net size over a 10-year period.

2) Cultivated populations of Raven's manzanita are perpetually maintained at two or more botanical gardens. Populations must include 50 daughter clones of the original Presidio plant, with an additional goal of 50 seedling-grown plants with at least two clonal replicates each.

3) Five or more spontaneously reproducing new populations (comprising at least five daughter clones each) are established in reserves on bedrock outcrops in San Francisco outside the Presidio, preferably in proximity to historic localities. At least three reserves must be on serpentine substrates. New colonies must show net growth 5 years after transplanting with intensive maintenance and 5 years after cessation of maintenance.

4) The taxonomic relationships and reproductive biology of Raven's manzanita are studied.

Estimated Costs of Recovery: Approximately **$ 17,302,500** (plus costs to be determined).

Date of Recovery:
Raven's manzanita: If recovery criteria are met, downlisting to threatened could occur by 2030.
San Francisco lessingia: If recovery criteria are met, downlisting to threatened could occur by 2020, and delisting could occur by 2030.

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I. INTRODUCTION

A. Scope and Purpose of the Recovery Plan

The two federally listed plant species addressed in this recovery plan are endemic to the San Francisco Peninsula: San Francisco lessingia (*Lessingia germanorum* Cham.), an annual herb of older sand dunes and similar sparsely vegetated coastal sand deposits (Lane 1993); and Raven's manzanita (recently treated taxonomically as *Arctostaphylos hookeri* G. Don ssp. *ravenii* P. Wells), a prostrate evergreen shrub found naturally only on certain types of Franciscan formation bedrock outcrops, particularly serpentine (U.S. Fish and Wildlife Service 1984). This recovery plan merges an update of the Raven's Manzanita Recovery Plan (U.S. Fish and Wildlife Service 1984) with a new plan for the recovery of San Francisco lessingia, and addresses actions that would benefit other federally listed species that are ecologically associated with these principal species within this geographic area, but are covered comprehensively in other recovery plans. Other federally listed plant species, covered principally in other recovery plans but sharing potential habitat and geographic range, are two annual herbs: a local serpentine endemic, Presidio clarkia (*Clarkia franciscana*), and the rare but wide-ranging beach layia (*Layia carnosa*), restricted to coastal dunes (U.S. Fish and Wildlife Service 1998*a*, 1998*b*).

The current geographic distributions of San Francisco lessingia and Raven's manzanita have been markedly reduced by habitat loss in San Francisco. Populations occur primarily within small, highly altered local remnants of dune and bedrock outcrop vegetation on former military lands of the Presidio. Herbarium records indicate that San Francisco lessingia was a local element of some phases of coastal dune scrub communities on the extensive sand dune sheet of San Francisco, and are consistent with records of many historically associated dune plants (Appendix I). It is associated with areas of sparse, low vegetation cover in older dunes. Raven's manzanita occurred in local abundance with a closely related subspecies from which it had not been distinguished until recent decades (Franciscan manzanita; *Arctostaphylos franciscana*, synonym = *Arctostaphylos hookeri* ssp. *franciscana*). Both manzanitas occurred on scattered exposures of bedrock outcrops composed of serpentine and greenstone (mafic and ultramafic igneous rocks, derived from altered minerals of deep magmas rich in heavy metals) (U.S. Fish and Wildlife Service 1984). Both manzanitas formerly occurred together at several sites. A single individual of Raven's manzanita exists in the wild today, but Franciscan manzanita now exists only in cultivation.

Most of the dune ecosystem and local bedrock outcrop plant communities of San Francisco County have been eliminated. Recovery of these listed species within protected and restored portions of their respective ecosystems is possible, however, and is the ultimate goal of this recovery plan. The geographic and ecological focus of this recovery plan, therefore, is on semi-natural vegetation of old dunes and bedrock outcrops on the few remaining undeveloped portions of the San Francisco Peninsula. The purpose of recovery is to reinforce or reestablish viable populations of San Francisco lessingia and Raven's manzanita, and their associated species of concern, in managed urban reserves of semi-natural vegetation, incorporating natural ecological dynamics, patterns, and processes to the greatest extent practical. These areas are found in the southwestern part of the Presidio, lands of the Golden Gate National Recreation Area, portions of urban parks, and on undeveloped private and municipal lands. Because of the essentially urban land use context, recovery objectives necessarily depend on some active vegetation management and integration with public recreational uses of urban parklands.

Two other federally listed plant species (U.S. Fish and Wildlife Service 1993, 1994) historically occurred on the northern San Francisco Peninsula in wetland habitats, and are treated in other recovery plans: California sea-blite (*Suaeda californica* S. Watson) and marsh sandwort (*Arenaria paludicola* Robinson).

California sea-blite is a gray-green shrub in the goosefoot family (Chenopodiaceae) that is now restricted to sandy high salt marsh edges of Morro Bay. San Francisco Bay populations of this species reported from the early 20th century (Jepson 1911, Howell *et al*. 1958) are now extinct. California sea-blite is planned for reintroduction at the Crissy Field barrier beach and salt marsh restoration project in the Presidio. The reintroduction of this species to San Francisco Bay salt marshes, and its recovery, are treated in the Draft Recovery

Plan for Tidal Marsh Ecosystems of Central and Northern California (U.S. Fish and Wildlife Service, in prep.).

Marsh sandwort is a low-growing clonal perennial herb in the pink family (Caryophyllaceae). This species is restricted to coastal sedge marshes, lagoon edges, and swampy thickets at widely disjunct localities, including Black Canyon Lake (San Luis Obispo County, the only currently verified population), Presidio marsh (now Crissy Field, San Francisco; Brandegee 1892, Howell *et al*. 1958), Santa Cruz and San Bernardino Counties, and the Tacoma area of Washington State. It has also been reported from Mexico (U.S. Fish and Wildlife Service 1998*c*). It was among the first plants in San Francisco to become locally extinct early in the city's history (Behr 1892). Neither marsh sandwort nor California sea-blite overlap ecologically with the dry, terrestrial, sparsely vegetated habitats of the species covered in this plan. Marsh sandwort recovery is treated comprehensively in the Draft Recovery Plan for Marsh Sandwort and Gambel's Watercress (U.S. Fish and Wildlife Service 1998*c*).

In addition, the coastal scrub and grassland of the San Francisco Peninsula has historically supported habitat for the San Francisco endemic, Xerces blue butterfly (*Glaucopsyche xerces*), the first butterfly known to have become extinct in the history of the United States (Powell and Hogue 1979). The area also supported habitat for the endangered Myrtle silverspot butterfly (*Speyeria zerene myrtleae*), a species formerly associated with coastal scrub and grassland from San Mateo to Marin Counties and currently extirpated south of the Golden Gate. Its recovery is addressed in the Recovery Plan for Seven Coastal Plants and Myrtle Silverspot Butterfly (U.S. Fish and Wildlife Service 1998*b*). The bay checkerspot butterfly (*Euphydryas editha bayensis*) is a federally threatened subspecies associated with serpentine habitats in the Bay area; its recovery is treated in the Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (U.S. Fish and Wildlife Service 1998*a*).

B. Coastal Dunes and Bedrock Outcrops of the Northern San Francisco Peninsula: Physical and Ecological Background

1. The San Francisco Dune System

a. Geomorphology and Evolution of the San Francisco Dune System. Prior to urbanization, the San Francisco dune system was among the largest in California (Cooper 1967). The dune sheet (a continuous mantle of wind-blown sand covering underlying substrate) extended from Land's End to south of Lake Merced (8 kilometers [5 miles]), and reached across the entire Peninsula (nearly 12 kilometers [7.5 miles] wide near the north end of the Peninsula) (Schlocker 1974) (Figure 1). The dune system of San Francisco is relatively isolated: the nearest coastal dune sheets of comparable size are at Point Reyes and Monterey Bay. The modern isolation of the San Francisco dune system is dependent on sea level. During periods of low sea level in the Pleistocene and early Holocene epochs, a broad coastal plain and delta were exposed far offshore from modern shorelines (Schlocker 1974, Atwater *et al*. 1979, Howard 1979). Coastal plain shorelines typically develop barrier beach coasts that support dune systems (Leatherman 1979, Davies 1980), so antecedents of modern central coast dune systems may have been widespread or continuously distributed along the central California coast during the many periods of glacial low sea levels during the Pleistocene epoch.

The western portions of the San Francisco dune sheet were described in the early 19th century as large expanses of relatively unvegetated, desert-like sand with wavy topography (Cooper 1967), suggesting extensive transverse dunes (dune ridges like giant ripples, elongated perpendicular to dominant winds) similar to those found on the dune sheet of Coos Bay in Oregon. Photographs of the "outer lands" of San Francisco from the 1860's reveal large expanses of mobile sand with discrete vegetated dune hummocks (G. Gaar unpublished local historic photography 1999). Mobile, sparsely vegetated or bare transverse dunes are evident in large undeveloped tracts of the Sunset district (south of Golden Gate Park) in 1930's aerial photographs (U.S. Army Corps of Engineers, San Francisco District, file information), and were observed by Schlocker in 1937 (Schlocker 1974). The nearest dune system persisting today with comparable but smaller

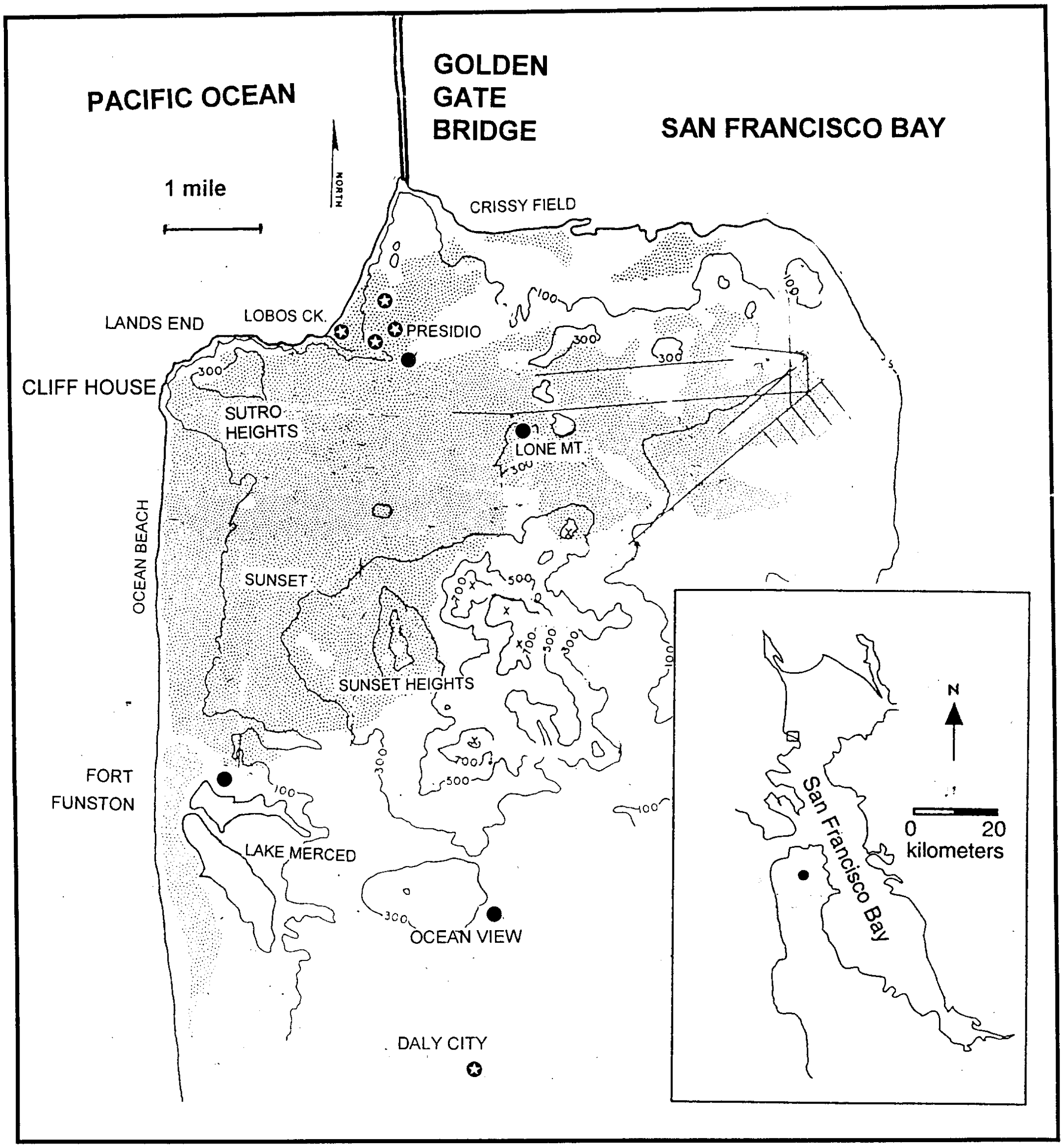

Figure 1. Approximate distribution of San Francisco dune sheet with unconsolidated surface deposits of wind-blown sand (Schlocker 1974, Cooper 1967, and U.S. Coast survey T-sheets from the 1850's). The relationship between the landward extent of the dune sheet and the bay shoreline has been obscured by bay fill. Approximate modern localities of San Francisco lessingia are shown in circled stars. The extirpated historic collection localities are shown in solid black circles. Lake Merced and Ocean View locations are generalized and not site-specific.

scale transverse dunes is at the outer Dillon Beach dune complex at the mouth of Tomales Bay, Marin County. San Francisco and Dillon Beach dunes both developed ponds and wetlands in depressions between dunes (Cooper 1967), probably fed from dune-dammed streams, springs, and seasonally high groundwater tables, as occurs at Dillon Beach dunes today (P. Baye unpublished data 1997-1998).

More eastern and interior San Francisco dunes were described as covered with scrubby trees (mostly coast live oak) and shrubs (Howell *et al*. 1958, Clary 1980), and were therefore probably much older than dunes of “western lands” (Cooper 1967, Schlocker 1974). Local dune sheets, independent of the main sheet that extended eastward from Ocean Beach, were also found in association with beaches along the north shore of the Peninsula, such as Baker Beach, the Presidio sand spit and Strawberry Island (now Crissy Field), and Black Point (former shoreline southeast of Crissy Field) (Cooper 1967). Apparently ancient small remnants of dune soils also occur within portions of serpentine landslides of the Presidio bluffs (northeast of Baker Beach), Sutro Heights, and Land’s End (P. Baye, pers. observ.), indicating former presence of wide beaches (sand sources) and climbing dunes along what are now steep, narrow, erosional sand and boulder beaches.

The San Francisco dunes were oriented with northwest winds, probably due to local topographic deflection of offshore winds that otherwise tend to be more southwesterly (Cooper 1967). Deflection of winds by local topography caused local major anomalies in dune trends such as the north-south trending dune tongue west of Laguna Honda, in the lee of Sunset Heights (Figure 1). The eastern portions of the dune sheet, as well as areas sheltered by hills of Franciscan bedrock, included longitudinal dunes and irregular partially-eroded deposits with vegetation cover of scrub and low oaks (Clary 1980). Climbing dunes ascended Franciscan bedrock hills (Buena Vista, Mt. Sutro, Sutro Heights, Sunset Heights, Lone Mountain) to heights over 180 meters (600 feet) in elevation (Schlocker 1974), often thinning to sand veneers over underlying soil and bedrock. West of Lake Merced, the dune sheet is perched on eroding marine bluffs (and buried soils) composed mostly of weakly consolidated, uplifted sand deposits of the Merced formation (Pleistocene sandy “fossil” marine and dune deposits that rise abruptly at Fort Funston; Schocker 1974). Evidence based on sand mineralogy and transport alongshore suggests that erosion of Merced deposits has been a principal long-term source of sand for the San Francisco dune system (Cooper 1967, Schlocker 1974). The dune sheet also overrides the similar poorly consolidated sand deposits of the Colma formation east of Lake Merced (Bonilla 1965).

The modern San Francisco dune system is probably derived from a composite of earlier and later generations of dunes deposited during the Pleistocene (glacial) epoch and recent post-glacial (Holocene) times (Schlocker 1974). Cooper (1967) identified two discrete advances or episodes of mobility in California dune systems, based on comprehensive comparative analysis of Pacific coast dune systems. The earlier advance, "Episode I," which may have corresponded with low glacial/early post-glacial (late Pleistocene/early Holocene) sea level and wide sandy coastal plains, corresponds with remnant landward dunes with well-developed chaparral, mature dune scrub and soil, grassland, or oak woodland. The later "Episode II" dune advance is associated with (or grades into) recent depositional environments. The outer mobile transverse dunes of the western parts of San Francisco were apparently "Episode II," or later Holocene deposits.

Urbanization has eliminated evidence of probable "Episode I" dune boundaries in San Francisco, but these boundaries are identifiable in dune systems north and south of San Francisco (Bodega Head, Dillon Beach, Monterey Bay; Cooper 1967). Traces of highly weathered and organic-stained old dune soils in landslides of the Presidio bluffs, and remnant coast live oak stands on old dune soils in Golden Gate Park may represent remnants of "Episode I" dunes. Soil properties of older dunes affect the diversity of the plant communities they support (Ranwell 1972). The former dunes at the east end of the City supported oak woodland or mature dune scrub with well-developed soil profiles and weathered organically-stained sand. This vegetation-soil unit possibly represents "Episode I" dunes of early Holocene or late Pleistocene age.

The dunes perched above the bluffs of the Merced formation may be derived from mixed sources of sand by wind erosion of: (1) consolidated, weathered yellow-brown Merced formation sands exposed in the marine scarp; (2) loose, unconsolidated sand of slope failures in Merced deposits; and (3) unweathered gray-white sand transported directly from the beach. The development of new dunes from reworked ancient sand from bluffs, sometimes mixed with recent sand, was described for the former Laguna Salada dunes located to the south of San Francisco (Cooper 1967), and can also be observed today directly above the low sandy bluffs at the south ends of Monterey Bay and Point Reyes beaches (P. Baye unpublished data 1997-1999). Today little of the mobile sand perched above the Merced bluffs is derived directly from the beach, as is indicated by the lack of wind-shadow dune deposits on the bluffs. These perched dunes have some soil characteristics of the much older, weathered sand deposits from which they were derived. Similarly, the large climbing dunes at the north end of Baker Beach appear to be relict deposits of a truncated, formerly more extensive dune system, with low modern rates of sand transport directly from the beach. This condition is indicated by landward-dipping beds in erosional dune scarps at the foot of the dune, weathered mineral films on the dune sand, and the lack of wind-shadow sand deposits at the back of the beach (P. Baye unpublished data 1998). In contrast, Ocean Beach, along the western shore of the City, periodically develops high rates of onshore wind transport of sand during phases of natural shoreline widening (P. Baye, pers. observ. 1984-1999). Thus, some San Francisco dune remnants today are truly relict (residual from former environments, not regenerated by modern physical and ecological processes), while some dune remnants are actively regenerated by modern processes.

The topography, stability, and soil of San Francisco dune remnants are also highly modified by residual effects of past introduction of dune-stabilizing vegetation, even where the original planted vegetation has vanished. Dune stabilization in San Francisco began in the 1870's with the introduction of European beachgrass (*Ammophila arenaria*), which successfully stabilized otherwise uncontrollable mobile dunes, and created steep, hummocky topography. Yellow lupine *(Lupinus arboreus*), native to the region, was planted to enrich sandy soils with organic nitrogen, in preparation for tree plantings. Iceplant (*Carpobrotus edulis* and hybrids) strongly stabilizes both mobile and relatively stable dunes, and planted stands of trees and shrubs (e.g., Monterey cypress, *Cupressus macrocarpa*; blue gum, *Eucalyptus globulus*; wattle, *Acacia* spp. [U.S. Fish and Wildlife Service

1998*b*, McLaren 1924]) act as strong baffles to dune-forming winds, and add abundant organic matter to dune soils.

b. Native Vegetation and Flora of the San Francisco Dune System. The original San Francisco dune system supported a species-rich vegetation and contained a wide spectrum of dune forms and successional stages. The character of the historic dune system can be inferred approximately from: (1) modern observations of comparable, protected dunes of the central coast; (2) historic botanical records (Bolander 1863, Brandegee 1892, Kaufeldt 1954, Howell *et al*. 1958, and old herbarium collections); and (3) historic photographs (Greg Gaar unpublished photographic archives 1999). Historic descriptive accounts and interpretations (Ramaley 1918, Cooper 1967) are also valuable sources of information. The plant species reported or collected from these dunes are shown in Appendix I.

The outermost (western) parts of the system along Ocean Beach consisted of mobile, mostly unvegetated sand masses (irregular wave-like transverse dunes) and relatively sparse, hummocky vegetated foredunes of various dimensions, with deflation plains (broad shore-parallel moist depressions) between them. Foredune plants were probably limited to the few species capable of tolerating conditions of strong sand mobility, such as beachbur (*Ambrosia chamissonis*), yellow sand-verbena (*Abronia latifolia*), and occasionally dunegrass (*Leymus mollis*) or beach saltbush (*Atriplex leucophylla*) at the seaward end. Silvery beach-pea (*Lathyrus littoralis*) occurred at least locally near Lake Merced, probably in relatively sheltered beach areas subject to occasional flooding. Pink sand-verbena *(Abronia umbellata*, probably mostly introgressants with *Abronia latifolia*) was also present in foredunes at least locally (collected by Peter Rubtzoff in 1959; CAS 538598[1]), as at Crissy Field, Presidio, today.

Dune slacks are topographically low, wide, and relatively flat areas within dune systems, most of which are wetlands (Ranwell 1972). These important elements

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1 This reference is a citation of an herbarium specimen. Abbreviations for herbaria are provided in the glossary, Appendix IV.

of the dune ecosystem vary in their modes of origin and degree of wetness, ranging from permanent ponds or dune lakes (e.g., Oso Flaco Lake, San Luis Obispo County) to seasonally wet rush meadows. Many dune slacks originate as deflation plains or hollows formed when wind erodes the dry sand surface down to the moist capillary fringes of fluctuating water tables, or down to resistant surfaces such as buried soil or lag deposits (concentrations of coarse sediment left behind following erosion of finer particles) (Carter 1988, Ranwell 1972). Deflation slack complexes are best developed in Oregon (Wiedemann 1965), but occur on the dunes of the central California coast at Dillon Beach in Marin County, and Tenmile Dunes and Manchester Dunes in Mendocino County (Cooper 1967, P. Baye unpublished data 1997). Dune slacks of the central California coast are also often associated with springs and seasonal streams perched on relatively impermeable sediment deposits beneath dune sheets, or drainages from adjacent terrestrial surfaces or aquifers (Cooper 1967, P. Baye unpublished data 1996-1999). Good examples of spring- or stream-fed dune slacks analogous with those formerly in San Francisco occur within the central coast region today at Point Reyes, Dillon Beach, Año Nuevo, and Franklin Point. Stream- or spring-fed slacks can be dammed by dunes, creating large seasonal or permanent ponds, riparian willow/waxmyrtle thickets, or marshes.

In San Francisco, there is historic evidence of both deflation and dammed-stream types of slacks. Major ponded dune slacks occurred in the lee of major dune ridges (Cooper 1967, Clary 1980), developing diverse rush/bulrush/sedge marsh, ponds, and swampy thickets of willows (*Salix* spp., mostly Arroyo willow, *S. lasiolepis*) and waxmyrtle (*Myrica californica*). Good examples of dune slack communities dominated by rushes, sedges, and forbs (herbaceous plants) are found at Point Reyes, Dillon Beach, and Año Nuevo/Franklin Point. These communities are probably like the ones formerly found in San Francisco. Dune localities of many marsh, submerged aquatic, and wet-meadow plant species, and descriptions of flats or hollows within dunes, were given by Brandegee (1892) and Howell *et al.* (1958) (see Appendix I). The only dune slacks remaining in San Francisco today are some of the ponds in Golden Gate Park, highly altered derivatives of the original natural ponds of dammed dune slacks.

Landward of the active transverse dunes, relatively more stable dunes occurred in various stages of succession and rejuvenation (remobilization). They supported either extensive stable cover of dune scrub or grassland vegetation, or a mosaic of blowouts (hollows derived from wind erosion of dunes) within a matrix of dune grassland and dune scrub. Dune scrub historically was, and still is, the dominant vegetation of stabilized dunes. Dune scrub communities of the central California coast have distinctive patterns of plant species abundance and composition that distinguish them from coastal scrub of bluffs and hills lacking dune sand. Dominant woody (to subshrubby) dune scrub species in San Francisco included false heather (*Ericameria ericoides*), silver or Chamisso's dune lupine (*Lupinus chamissonis*), coyote brush (*Baccharis pilularis*, a common coastal scrub species), dune wormwood (*Artemisia pycnocephala*; probably in areas of secondary blowouts), deerweed (*Lotus scoparius*), dune knotweed (*Polygonum paronychia*), and dune buckwheat (*Eriogonum latifolium*) (Bolander 1863, Behr 1888, Brandegee 1892, Kaufeldt 1954, Howell *et al*. 1958). The yellow bush lupine (*Lupinus arboreus*), which today is commonly found in dune scrub remnants and restoration sites, was apparently not a component of the San Francisco dune vegetation at the time of Bolander's early surveys (Bolander 1863). It was formerly a minor component of central California coastal dune scrub (Cooper 1936), although it was later broadcast-seeded into dunes to stabilize them (McLaren 1924, Clary 1980). Other shrubs, such as poison-oak (*Toxicodendron diversilobum*), California buckthorn (*Rhamnus californica*), and lizard-tail (*Eriophyllum staechadifolium*, a species typical of coastal scrub in general) were probably at least locally abundant elements of dune scrub; these species also persist locally today in San Francisco dune remnants. Oak woodlands dominated by dwarfed, shrubby coast live oaks (*Quercus agrifolia*) also developed locally in older dunes; very few persist today in some relict dunes of the Presidio (north of the Marine Hospital) and Golden Gate Park (around Fuchsia Dell and De Laveaga Dell). Another dominant shrub of coastal headlands of the Golden Gate, blue-blossom or California lilac (*Ceanothus thyrsiflorus*), is conspicuously absent on dune substrates.

Common herbaceous species associated with San Francisco dune scrub include man-root (*Marah fabaceus*), bracken fern (*Pteridium aquilinum*), live-forever (*Dudleya farinosa*), miner's-lettuce (*Claytonia perfoliata*), maritime bromegrass

(*Bromus carinatus* var. *maritimus*), and many other species also found in dune grassland (see Appendix I, and below). Indian paintbrush (*Castilleja affinis* ssp. *affinis*) was formerly a common element of stable dune scrub in San Francisco (Howell *et al.* 1958; then treated as Monterey Indian-paintbrush, *Castilleja latifolia*), but today, in scrub remnants where it was formerly recorded, it is infrequent and local (Howell *et al*. 1958, P. Baye unpublished data 1997-1999). A more common coastal Indian-paintbrush, Wight's Indian-paintbrush (*Castilleja wightii*), appears to be absent from San Francisco dunes (though local Indian-paintbrushes are sometimes easily confused with this strongly sticky-glandular species), despite its frequency on San Mateo County coastal bluffs from Pacifica south and its former occurrence near Lake Merced and Mt. Davidson (Howell *et al*. 1958). Bare or sparsely vegetated gaps within coastal dune scrub intergrade with dune grassland, and support annual herbs such as popcorn-flower (*Cryptantha leiocarpa*), coast fiddleneck (*Amsinckia spectabilis*), wild heliotrope (*Phacelia distans*), dune gilia (*Gilia capitata* ssp. *chamissonis*), San Francisco spineflower (*Chorizanthe cuspidata*), annual plantain (*Plantago erecta*, usually on older dune soils), and annual evening-primroses (*Camissonia contorta* and *Camissonia micrantha*) (Howell *et al*. 1958; P. Baye, pers. observ. 1984-1999).

Dune grassland and forbland intergrade with central coast dune scrub vegetation. Dune grassland and forbland are characterized by prevalence of grasses and grasslike species or herbaceous plants (forbs) rather than the woody species of dune scrub. Many of the same species occur in different relative abundance in dune scrub. Stands of dune grassland and forbland are still well-represented in other central coast dune systems (Point Reyes and Dillon Beach dunes, Monterey Bay; P. Baye, pers. observ. 1984-1999), but are now poorly represented in San Francisco. Small and recently-formed stands of dune grassland occur above northeast Baker Beach, and in small remnant patches at Sunset Heights (P. Baye, pers. observ. 1998).

Among the common to dominant perennial grasses and grasslike plants of dune grassland (also in openings in dune scrub) in San Francisco were dune bluegrass (*Poa douglasii*), pacific wildrye (*Leymus pacificus*), red fescue (*Festuca rubra*), maritime brome (*Bromus carinatus* var. *maritimus*), and at least locally, salt rush

(*Juncus lesueurii*; sometimes interpreted as *Juncus breweri,* both closely related to wire rush, *Juncus balticus*) (Brandegee 1892, Howell *et al*. 1958).

Herbaceous perennial plant species of dune grassland included dune goldenrod (*Solidago spathulata*), sand mat (*Cardionema ramossisimum*), California poppy (*Eschscholzia californica*—perennial dune ecological race), beach strawberry (*Fragaria chiloensis*), California phacelia and common phacelia (*Phacelia californica, Phacelia distans*), sea-pinks (*Armeria maritima*), yarrow (*Achillea millefolium*), man-root or marah (*Marah fabaceus*), beach evening primrose (*Camissonia cheiranthifolia*), as well as creeping perennial foredune species. The tall, colony-forming dune-tansy (*Tanacetum camphoratum*) occurred in dune scrub or forbland at the southern limit of its range in San Francisco.

Common annual herbs included within dune grassland were essentially the same as those in gaps within dune scrub, listed above and in Appendix I. Dune grasslands also included species now rare or extirpated in local dune remnants, such as the showy colony-forming broadleaf purple owl's-clover (*Castilleja exserta* ssp. *latifolia*; not recently reported), and sky lupine (*Lupinus nanus*; now locally rare on dunes) (Brandegee 1892, Howell *et al.* 1958).

Ecotones (transitional edges) of dune plant communities occurred where dune sand deposits thinned out to veneers over bedrock, ancient Pleistocene sand deposits, or dune slacks, with corresponding intermediate variations in plant species associations. Remnant examples of dune ecotones in San Francisco are found at Sunset Heights hilltops and around Sutro Heights (P. Baye, pers. observ. 1993-1999). The turf-forming sedge *Carex praegracilis* and the colonial rush *Juncus lesueurii* and its allies probably occurred in dune/dune slack ecotones; these species were present in San Francisco and occur in dune slacks elsewhere on the central coast (P. Baye unpublished data 1995-1999).

Other types of sand deposits on the northern San Francisco Peninsula also support many elements of the region's coastal dune vegetation. Ancient, weakly consolidated sandy deposits of sediment from "fossil" alluvial, lake, beach, dune, and estuarine environments of the Merced and Colma formations (Schlocker 1974) date from the Pleistocene epoch. They are extensively exposed in San

Francisco and Daly City (Bonilla 1965, Schlocker 1974). Merced and Colma deposits typically form yellow-brown coastal bluffs that erode and supply sand to modern beaches and dunes, and directly merge with them in places (e.g., Fort Funston, north end of Ocean Beach). They also occur at inland locations beyond the Holocene (post-glacial) dune sheet (e.g., east of Lake Merced, Daly City, and elsewhere; Bonilla 1965). The Colma sediments were probably derived from extensive tidal lagoon sand shoals and adjacent barrier beach and dune environments (Schlocker 1974). Some sands within these deposits resemble well-sorted dune sands, but contain significantly more clays, silts, and mineral weathering products, giving them more soil-like properties. Coastal scrub and grassland vegetation similar in composition and structure to those of coastal dunes is associated with these Pleistocene sand deposits, including the southernmost locality of *Lessingia germanorum* (McClintock *et al*. 1990).

c. Dynamics of Dune Vegetation. The structure and composition of dune scrub and grassland vegetation are closely connected to the geomorphic dynamics of sand transport within dune systems, particularly in relation to dune blowouts. Blowouts in dunes that have previously been stabilized by vegetation and initial soil development reactivate mobility of buried sand, creating zones of upwind erosion and downwind sand accretion. Blowouts establish patches of secondary vegetation succession, gaps in which local pioneer vegetation can establish. Blowouts arise through various interacting influences, such as animal burrowing, fire, and drought-related dieback of vegetation. They occur at various scales, ranging from minor patches a few meters wide, to reactivation of whole ridges (Cooper 1958, Ranwell 1972). Blowouts of different sizes and ages within a matrix of dune vegetation undergo secondary succession from dune scrub back to dune forbland or grassland. The variation in size and ecological maturity of blowouts within dune systems can maintain a mosaic of vegetation gaps available for recolonization, and diverse vegetation types arising from variable local influences and stages of development. Most blowouts in San Francisco dune remnants appear to be the result of recent human disturbances, especially trampling of vegetation (P. Baye, pers. observ. 1984-1999).

Blowouts in modern dunes of the central California coast are impeded by dense cover of invasive sand-stabilizing vegetation, particularly European beachgrass

(*Ammophila arenaria*), deliberately introduced to San Francisco around 1870 for dune stabilization purposes; Jepson 1911, McLaren 1924, Clary 1980, U.S. Fish and Wildlife Service 1998*b*) and iceplant (*Carpobrotus edulis)* and related hybrids. By the mid-20th century, these and other nonnative species dominated remnant San Francisco dune vegetation (Kaufeldt 1954). Blowout vegetation development is also thwarted by wind-sheltering effects of large nonnative trees (particularly Monterey cypress, *Cupressus macrocarpa*, and blue gum, *Eucalyptus globulus*, planted on San Francisco dunes for windbreaks and planted "forest" cover; McLaren 1924, Clary 1980). The elimination of burrowing, grazing, and trampling activities by native mammals also probably contributed to the reduction of blowouts in remnant old dunes in San Francisco. In contrast, intensive recreational use of dunes, particularly in foredune areas near beaches, can either compensate for the over-stabilizing effects of nonnative vegetation, or over-compensate and exaggerate the distribution and abundance of mobile, unvegetated sand. At Ocean Beach and Fort Funston, intensive trampling and footpaths frequently enlarge to blowouts. Since the construction of the Great Highway along Ocean Beach in the foredune zone, the foredunes have been periodically stabilized by placement of earthen fill material and plantings of European beachgrass over most of its length.

2. San Franciscan Bedrock Outcrops and their Vegetation

a. San Francisco Bedrock Outcrops. Bedrock outcrops occur scattered throughout San Francisco (Schlocker 1974). Many persist as steep, undevelopable knobs on the crests of hills up to 281 meters (922 feet) above sea level, or high, unstable coastal bluffs subject to frequent landslides (Schlocker 1974). The bedrock outcrops in San Francisco are folded and uplifted Jurassic and Cretaceous sedimentary rocks with intrusions of igneous (volcanic) rocks of the Franciscan formation. Franciscan rocks include massive and bedded sandstones, shale, chert, greenstone (mostly basalts), serpentinite, gabbro-diabase, and mixed sheared rocks along fault zones. They range from erosion-resistant basalt and chert, to serpentine rocks that range from massive, hard, and dense to intensely sheared, soft, friable, and plastic material (Schlocker 1974). Serpentine rocks are derived from weathering or modification of igneous ultramafic rocks (rocks originating as deep magmas rich in heavy metals). Serpentine rocks are particularly relevant to distinct local vegetation, since the soil chemistry of serpentine typically imposes extremes of mineral nutrition and toxicity (particularly low calcium, high magnesium, and heavy metals) for many plants. Serpentine soil results in exclusion or growth suppression of many plant species and selects for a narrow range of endemic serpentine-adapted species or populations. Many serpentine plants are narrow edaphic endemics, species of extremely restricted ecological and geographic distribution based on soil type (Kruckeberg 1954, 1984; Raven and Axelrod 1978; U.S. Fish and Wildlife Service 1998*a*).

Most bedrock outcrops of the interior parts of San Francisco are characterized by steep topography, thin, dry soils, and bare rock, conditions that maintain permanently sparse vegetation cover, at least locally. The extensive serpentine soils and rocks of the Presidio bluffs, along the south shore of the Golden Gate (Figure 2 and Figure 3) occur in both structural outcrops and in landslides. At some locations in the bluffs, the exposed serpentine has deeper soft soils that undergo extremes of saturation and drying, frequent local seeps and near-surface groundwater, as well as stronger direct exposure to marine fog (P. Baye, pers. observ. 1984-1999). The largest outcrops of serpentine occur on Potrero Hill (Schlocker 1974). Major outcrops of sheared rocks and greenstone are shown in Figure 3. Significant bedrock outcrops occur at Mount Davidson Park, Twin Peaks, Mount Sutro, the Duboce U.S. Mint, Sunset Heights, McLaren Park, Point Lobos, and other locations (Figure 2 and Figure 3), many of which are partially obscured by nonnative vegetation, or are isolated as small erratic remnants included within developed areas (e.g., serpentine at the Duboce U.S. Mint and near China Basin). Significant historic outcrops, now destroyed, occurred at the Masonic and Laurel Hill cemeteries in the Richmond district and at the former Protestant Orphan Asylum at Haight and Laguna streets, near the Duboce U.S. Mint (U.S. Fish and Wildlife Service 1984).

b. Vegetation of San Francisco Bedrock Outcrops. The vegetation associated with bedrock outcrops in San Francisco is variable today, including elements of remnant native vegetation as well as naturalized nonnative vegetation. Historically it included plant associations classified as coastal grassland (prairie) and variations of coastal scrub (Appendix II). No native trees are known to have

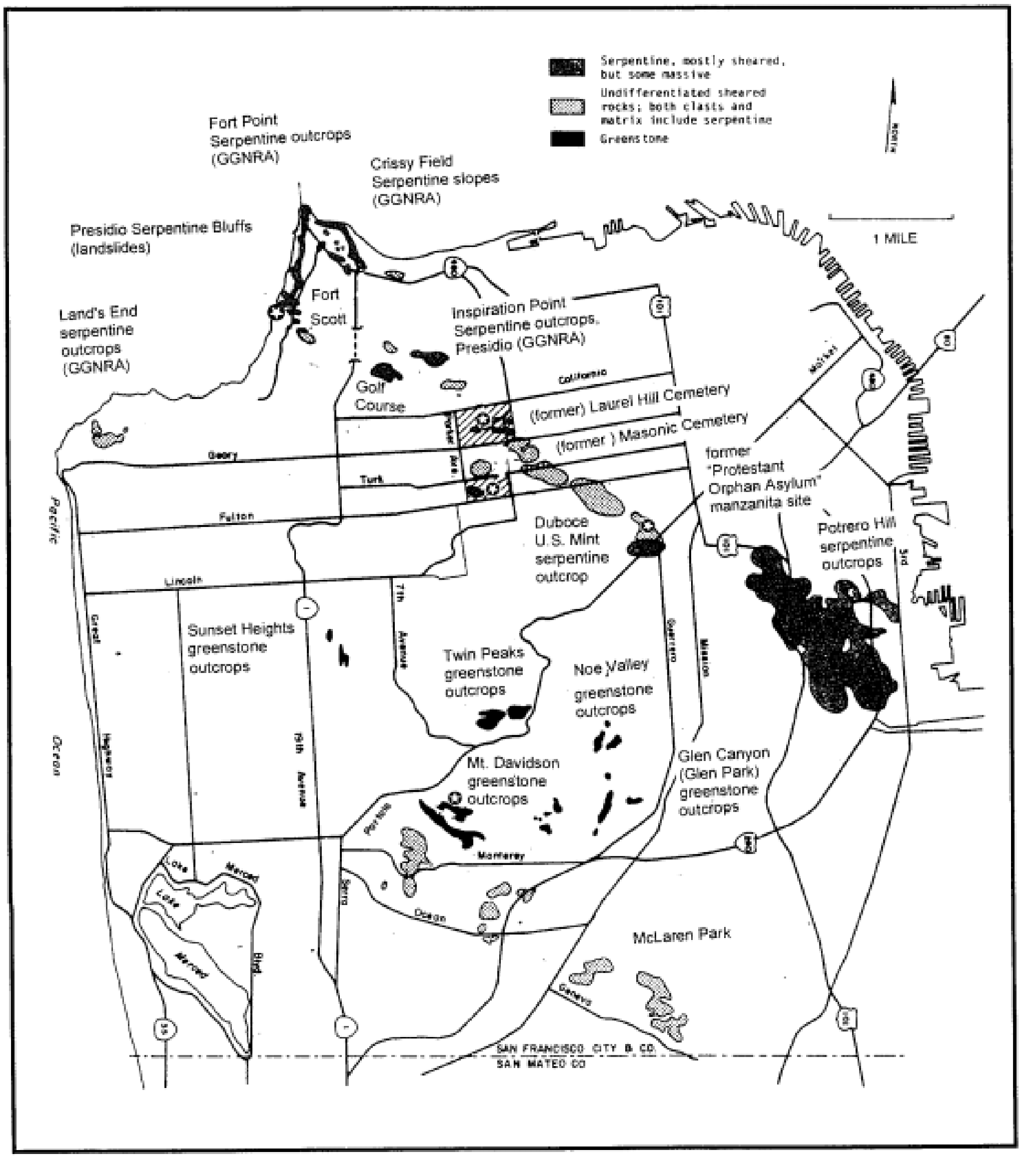


Figure 2. Localities of serpentine and greenstone bedrock outcrops in San Francisco. Areas shown include urbanized and undeveloped sites. Some otherwise urbanized sites include local outcrops (road cuts, graded slopes) that support vegetation. Approximate localities of historic Raven's manzanita sites are indicated by circled stars.

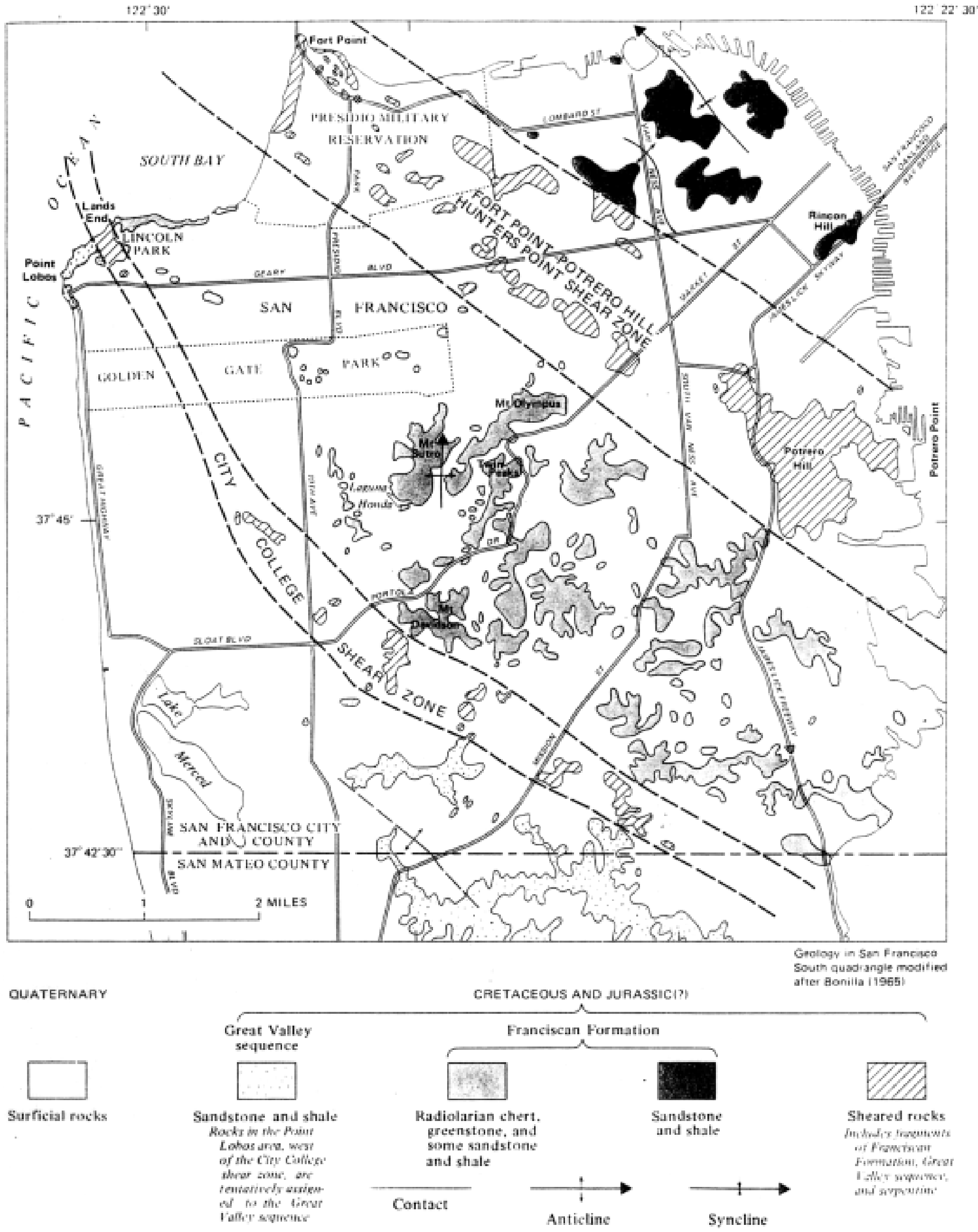


Figure 3. Geological control of Raven's manzanita habitat. Distribution of shear zones, containing sheared rocks with serpentine outcrops, and Franciscan formation outcrops including greenstone. (Reproduced from Schlocker, J. (1974) *Geology of the San Francisco Quadrangle, California*, U.S. Geological Survey Professional Paper 782, United States Government Printing Office, Washington [Figure 63]).

originally been associated with serpentine or other bedrock outcrops in San Francisco (Bolander 1863, Cooper 1875, Behr 1892, Brandegee 1892), although introduced Monterey cypress (*Cupressus macrocarpa*), Monterey pine (*Pinus radiata*), and blue gum (*Eucalyptus globulus*) have colonized serpentine landslides of the Presidio (P. Baye, pers. observ. 1998). Many nonnative herbaceous species are able to colonize bedrock outcrops, including serpentine rocks. Species that are particularly invasive locally include jubata grass (*Cortaderia jubata*), filaree (*Erodium* spp.), iceplant (*Carpobrotus edulis* and hybrids), and wild oat (*Avena fatua*) (U.S. Fish and Wildlife Service 1984, P. Baye, pers. observ. 1993-1999). Invasive species that are able to colonize outcrops abundantly can eliminate the characteristic open, barren, or sparse structure of the vegetation. Slow-growing, short-stature native species, including serpentine endemics, probably are able to persist because of this characteristic open, low vegetation structure (Kruckeberg 1984), and are threatened by competition and habitat modification due to invasive nonnative plants (U.S. Fish and Wildlife Service 1984, 1998*a*).

In San Francisco, no unique native plant assemblages are associated with bedrock outcrops, even those on serpentine. However, many species and local variations in plant associations have distributions closely corresponding to these habitats (U.S. Fish and Wildlife Service 1998*a*). The historically documented distribution of local manzanita species was closely correlated with relatively barren bedrock outcrops, particularly of serpentine and greenstone (U.S. Fish and Wildlife Service 1984, Figure 2). Similarly, Bolander (1863) noted that some other manzanita species were closely associated with sandstone outcrops of the Oakland Hills, and Howell (1949) observed that most manzanita species in Marin County were associated with rocky, barren, steep slopes and ridges. Some thistles are frequently associated (Franciscan thistle, *Cirsium andrewsii*) or exclusively associated (Mount Tamalpais thistle, *Cirsium hydrophilum* var. *vaseyi*, and fountain thistle, *Cirsium fontinale* var. *fontinale*) with serpentine seeps (Keil and Turner 1993). Rare or uncommon species in the San Francisco flora that are relatively frequent on or exclusive to serpentine or other bedrock outcrops include Marin dwarf-flax (*Hesperolinon congestum*), evax (*Hesperevax sparsiflora*), and San Francisco gumplant (*Grindelia hirsutula* var. *maritima*) (Howell *et al*. 1958, Golden Gate National Recreation Area unpublished reports). Many other grassland species that formerly occurred in greater abundance in San Francisco (Wood 1996) are now restricted to the thin soils and steep slopes that have marginally escaped the adverse influences of urban development and nonnative vegetation.

II. BIOLOGY OF FEDERALLY LISTED SPECIES

A. San Francisco Lessingia (*Lessingia germanorum* Chamisso)

1. Description and Taxonomy

San Francisco lessingia is an annual herb in the aster family (Asteraceae) (Figure 4). Seedlings and young vegetative plants (Figure 4a) develop from unbranched rosettes of oblanceolate (spear-shaped but tapered at base, wide and rounded at tip) leaves. As the plant matures (Figure 4b), some lateral shoots elongate markedly and then branch profusely, developing a decumbent (growing mostly through lateral branches) growth habit. Mature plant heights can range from less than 5 centimeters (2 inches) in stunted plants, to 0.3 meter (1.2 feet) tall. Mature stems are reddish brown and are tomentose (with loose grayish woolly hairs). Leaves on mature stems are small (0.5 to 3.0 centimeters [0.2 to 1.2 inches]), most less than 1.0 centimeter (0.3 inch), pinnately lobed (branching from a single central vein), toothed or entire (lacking teeth and lobes), oblanceolate or long-tapered obovate (egg-shaped, but widest at the far end), and grayish-green due to dense woolly hairs (Figure 4c). Flowers in the aster family occur in flowerheads composed of many individual flowers (florets).Flowerheads function as individual units for pollinators and resemble individual flowers. In San Francisco lessingia, flowerheads appear from late summer through fall. They occur singly or in loose clusters at the ends of stems (Figure 4d). Depending on plant size, individuals may bear a few to hundreds of flowerheads. The bell-shaped involucre (a mantle of tiny leaf-like appendages called phyllaries that enclose the immature flowerhead) is 4 to 8 millimeters (0.15 to 0.3 inch) wide. Phyllaries are lance-shaped, with abruptly pointed tips. All florets within the flowerhead are disk florets (composite flowers within the flowerhead); ray florets (small individual flowers with strap-shaped corollas resembling single petals at the margin of the flowerhead) are lacking (Figure 4e). Each head contains from 20 to 40 disk florets. Each floret has a yellow corolla (series of petals that are united into a tubular to funnel-shaped deeply lobed structure), with brownish bands in the throat.The fruit is an achene (a seed-like dry fruit) 1 to 3 millimeters (0.04 to 0.12 inch) with tan or whitish pappus (hairy bristles that increase the dispersability of achenes in air currents, as in dandelion “blowballs”). No other annual

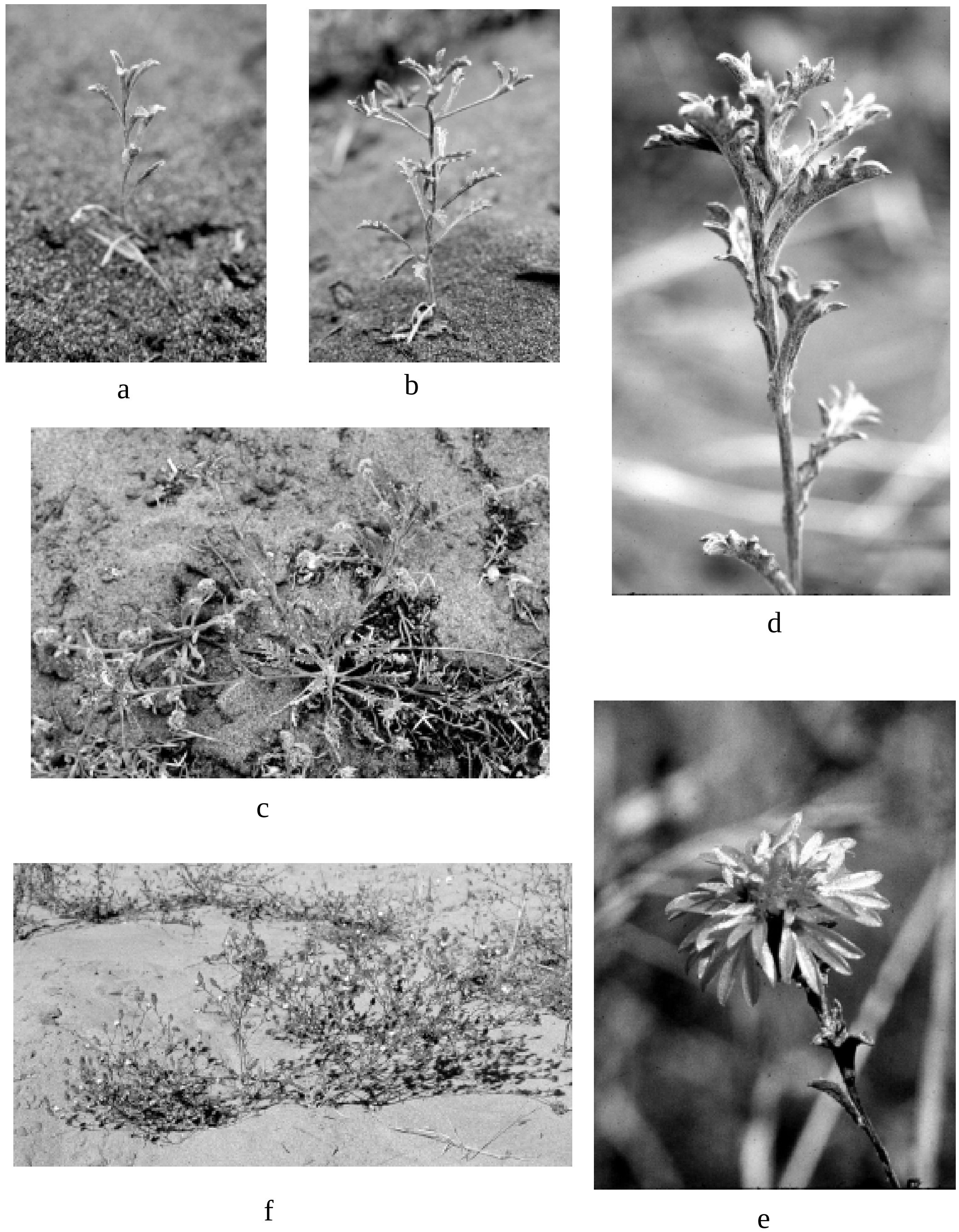


Figure 4. San Francisco lessingia (*Lessingia germanorum*). (a) unbranched juvenile plant; (b and c) branching juvenile plant, pre-flowering stage; (d) detail, vegetative shoot; (e) detail, flowerhead; and (f) mature plant, early flowering stage.

Lessingia species occur within the range of San Francisco lessingia on the San Francisco Peninsula, making it easy to distinguish (Howell 1929, Spence 1964, Lane 1993). San Francisco lessingia was originally collected and described as a species by Chamisso in 1829, based on specimens collected from sand dunes in San Francisco (Howell 1929), probably from the Presidio. *Lessingia germanorum* is the type species for its genus (the first plant selected by taxonomists to represent the group; the exemplar for all related species). Howell (1929) treated San Francisco lessingia broadly as a taxonomic entity, assigning all of the yellow-flowered taxa of *Lessingia* to 11 varieties of *Lessingia germanorum*. Howell treated the endemic San Francisco lessingia taxonomically as *Lessingia germanorum* Cham. var. *germanorum*. Meredith A. Lane's treatment of the genus *Lessingia* in California for the Jepson Manual (Hickman 1993) returned San Francisco lessingia to a narrow species concept, eliminating Howell's varieties by assigning them to other *Lessingia* species or elevating them to species rank. San Francisco lessingia is distinguished from other California species of *Lessingia* by the combined presence of yellow disk florets and lack of ray florets, and the general absence of glands on the foliage (or having only sparse, nail-shaped glands). Howell (1929) considered San Francisco lessingia to be a slightly modified form of the most primitive (ancestral) types of *Lessingia*.

San Francisco lessingia is currently considered a distinct species, most closely related to *Lessingia glandulifera* A. Gray var. *pectinata* Jeps. (Howell 1929, S. Markos, pers. comm. 1998). Hoover (1970) interpreted Eastwood specimens of *Lessingia* from the Santa Maria River bed in San Luis Obispo County as *Lessingia germanorum* var. *germanorum* (following Howell's classification), based on the nearly glandless condition. This specimen was collected within the range of *Lessingia glandulifera* var. *pectinata* (treated by Hoover as *Lessingia germanorum* var. *pectinata* (E. Greene) J. Howell), which occurs in essentially the same type of open, sandy coastal habitat, but in a restricted southern range (Howell 1929). Reevaluation of the genus based on molecular genetic data is likely to clarify systematic relationships within *Lessingia*, particularly with *Lessingia glandulifera* var. *pectinata* (S. Markos, pers. comm. 1998).

2. Historic and Current Distribution and Abundance

In the 19th century, San Francisco lessingia was reported or collected from numerous unspecified localities and two specific areas in San Francisco: one in the northwest, from the Presidio (near Lobos Creek) to Lone Mountain, and one in the southwest, near Lake Merced (Brandegee 1892, Table 1, Figure 1). Most early collection localities were highly generalized as “Presidio” or “San Francisco.” Herbarium sheets with specific collection localities from the 19th and 20th centuries clearly indicate that the historic distribution of San Francisco lessingia on the San Francisco Peninsula was considerably wider than today (Table 1). The modern restricted distribution of San Francisco lessingia is probably due to habitat loss, habitat alteration, and extirpation of populations (Spence 1964).

The northwestern San Francisco population of San Francisco lessingia included specific collection localities from dunes as far east as Fulton Street at Lone Mountain (*J. T. Howell* [1926], CAS 166038, [1927] CAS 166064; earliest collections here in the 1860's*:* *J.P. Moore*, no date, circa 1860's, CAS 9451; *A. Kellogg & W. G. W. Harford* [1868], CAS 9448) and as far west as Baker Beach at the mouth of Lobos Creek (CAS 491875, *P.H. Raven* [1954]). Some of the historic Presidio localities appear to be the same as those found today (*Spence* [1960] “sandy soil, roadside adjacent to golf links,” CAS 567670; “sandy area between U.S. Marine Hospital and Lobos Creek,” CAS 188634, *P. Rubtzoff* [1956]), but some are apparently extirpated (“Mountain Lake,” CAS 128600, *Goodman* [1954]); “Coastal bluffs near mouth of Lobos Creek,” (*Raven* [1954], CAS 491875) (Table 1).

a. Modern Presidio Populations. The Presidio populations are currently located at six sites, each one a few tens to hundreds of meters from the nearest neighboring colony (Figure 5). Population estimates from the Presidio are provided from Golden Gate National Recreation Area file information. Population sampling and estimation methods used by Presidio Natural Resources staff are described and evaluated by Wayne (1996) and Bode (1998). Site locations are shown in Figure 5.

Table 1. Historic locality and habitat data from herbarium specimens of *Lessingia germanorum*

Where duplicated specimens exist, label information from the more detailed account is cited. Bold type is added, not in original.

CAS - California Academy of Sciences
DS - Dudley/Stanford (at CAS)
JEPS - Jepson Herbarium (at UC Berkeley)
UC - University of California (Berkeley)

L. Abrams, Aug 31, 1901. CAS 145061. Sand dunes, **San Francisco** County.

H.G. Bloomer, 1868. CAS 190998. **San Francisco**.

T.S. Brandegee, July 1, 1890. UC 87998. **Marine Hospital**, San Francisco.

K. Brandegee, Sept. 1, 1901. UC87997. **San Francisco**.

K. Brandegee, July 12, 1905. UC 83863. **Lake Merced**, upper end. San Francisco.

K. Brandegee [as "MKC"], Aug. 1, 1886. JEPS16551. **San Francisco**.

K. Brandegee (no date) CAS 6438. **San Francisco**.

E. Cannon (no date) CAS 9452. **Presidio** Grounds (San Francisco).

J.W. Congdon, May 1881. CAS 6436. **San Francisco**.

W.R. Dudley, Nov 8, 1899. DS 593657. **Ocean View** Downs, San Francisco.

A. Eastwood, Aug. 7, 1913. CAS 3449. **Lake Merced**, San Francisco.

Goodman, Dr [sic]. Dec. 1, 1924. CAS 128600. **Mountain Lake**, San Francisco.

J.T. Howell, Oct. 19, 1924. CAS 166017. near **Lake Merced**, San Francisco.

J.T. Howell, Aug. 12, 1926. CAS 166021, UC 912539. Near **Lone Mountain**, in deep sand.

J.T. Howell 2233, Nov. 7, 1926. CAS 166038, JEPS 20555. Sandy open [....] near **Lake Merced**, San Francisco.

Table 1, continued.

J.T. Howell, Mar. 18, 1927. CAS 166064. Fulton Street east of St. Ignatius Church, San Francisco, a part of **Lone Mountain** slopes.

J.T. Howell, Sept. 10, 1927. CAS 166053. Grown in the Botany Garden, University of California, in Strawberry Cañon, from seed collected at **Lake Merced**, San Francisco.

J.T. Howell, Sept. 26, 1931. UC 473579. Sandy slope, **Presidio**, San Francisco.

J.T. Howell 8126, Sept 29, 1931. CAS 188634. Sandy slope, **Presidio**. San Francisco.

Jepson, W.L. Oct. 1, 1894. JEPS 20553. Hills near **Mountain** View **Lake** [Mountain Lake, San Francisco].

A. Kellogg & W. G. W. Harford, July 7, 1868. CAS 9448. **Lone Mountain**, San Francisco.

J. P. Moore, (no date, ca. late 1800's). CAS 9451. **Lone Mt.**

N. Pettibone, July 1894. CAS 346025. **Presidio**, San Francisco.

P.H. Raven, Aug. 22, 1954. CAS 491875, JEPS 16551. TOPOTYPE. Coastal bluffs near **mouth of Lobos Creek**, Presidio, San Francisco.

L. Rose, Sept. 9, 1941. CAS 305722, UC662638. Type locality. Associated with *Croton californicus* and *Baccharis pilularis* on coastal sand hills, **Presidio**, San Francisco. alt. 60 m.

L. Rose Oct. 21, 1961. DS 567812, JEPS 30082. **Presidio**, sandy flat. ca. 200 ft. [San Francisco].

L. Rose,. July 14, 1969. JEPS 59952. **Presidio, n of golf links.** Dry sandy flats.

P. Rubtzoff,. Aug 18, 1956. CAS 494874. Presidio Waste, sandy area **between U.S. Marine Hospital and Lobos Creek.**

W. Spence, 12 June 1960. CAS 567670, UC 1287362. Flowers deep lemon yellow with a reddish brown band in the throat. Growing in sandy soil, **roadside adjacent to golf links, Presidio**, San Francisco.

Mrs. E. C. Sutcliffe, May 1918. CAS 9450. **Presidio**, San Francisco.

Table 1, continued.

Summary of collection localities:

unspecified San Francisco localities	6
unspecified Presidio localities	7
Mountain Lake (Presidio)	2
Presidio Golf Links vicinity	2
Marine Hospital - upper Lobos Creek vicinity (Presidio)	2
Baker Beach, mouth of Lobos Creek (Presidio)	1
Lone Mountain	4
Lake Merced vicinity	5
Ocean View vicinity (Lake Merced?)	1

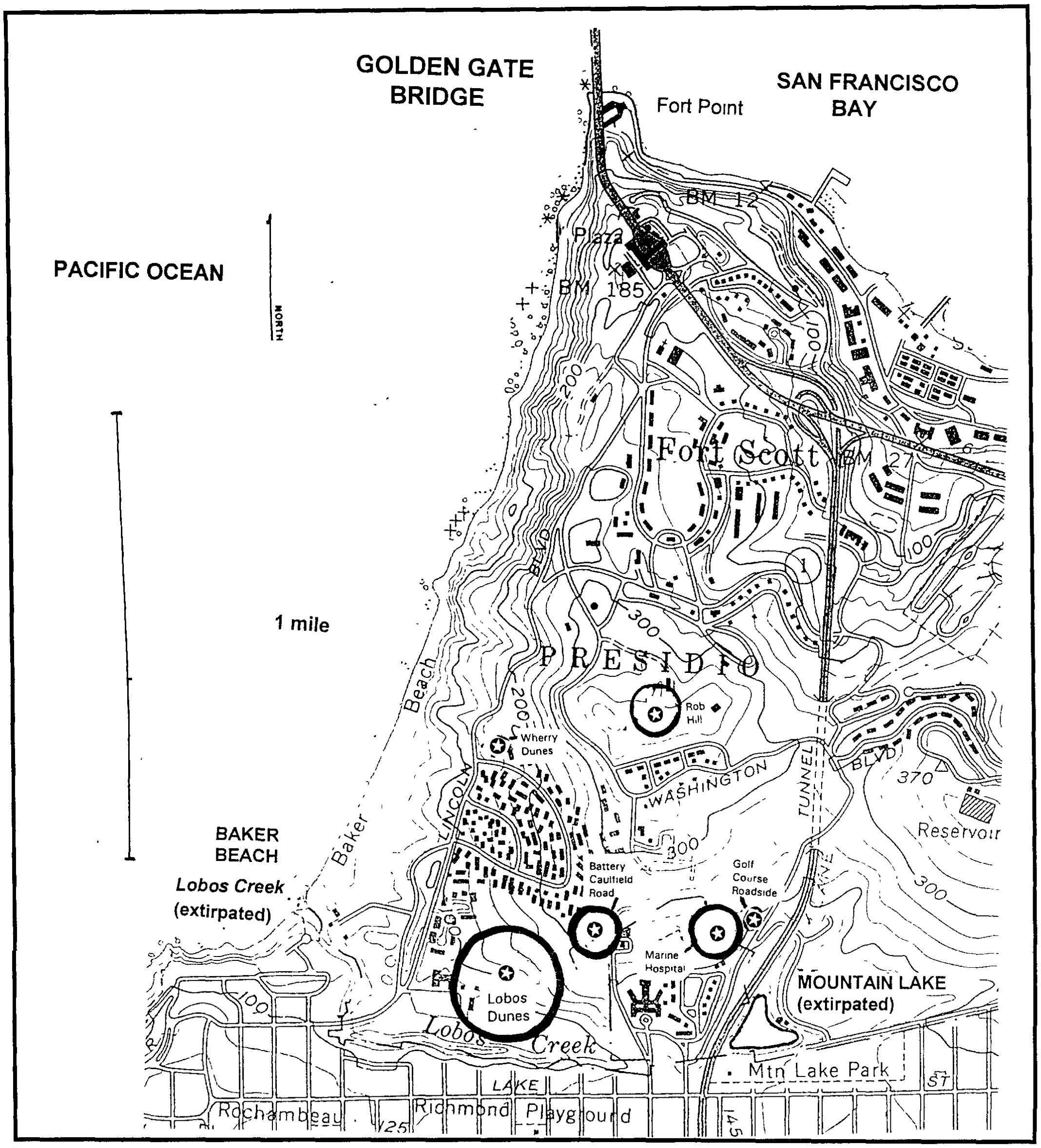


Figure 5. Approximate contemporary locations of San Francisco lessingia (*Lessingia germanorum*) in the Presidio, San Francisco. Circled stars indicate approximate locations of remnant San Francisco lessingia colonies. Outer circles indicate vicinity of probable or actual population spread.

(1) *The Lobos (Creek) Dunes site* is an area of early-succession stable dune scrub that was recently (1995-1997) restored by removal of nonnative trees and replanting locally propagated native vegetation (J. Cannon, M. Albert, pers. comm. 1996-1997). This restoration expanded the small (less than 0.2 hectare [0.5 acre]) remnant Lobos Creek population, which occurred on a formerly graded, disturbed, weedy, open space on mixed dune sand and fill substrates above Lobos Creek. The site is bordered by nonnative Monterey cypress groves and Lobos Creek's riparian zone. The restored dune area supporting San Francisco lessingia now occupies approximately 5.3 hectares (13 acres). After regrading the site and seeding with San Francisco lessingia, the population here has recently expanded from a few tens to hundreds of plants in the 1980's to an estimated 130,000 in 1997 and approximately 17,000,000 in 1998 (M. Albert, pers. comm. 1998). As replanted native dune scrub vegetation established after 1998, lessingia numbers adjusted to a lower, more sustainable range between 340,000 and 1,300,000 lessingia plants (M. Albert, unpublished data 2001). The rapid population changes of San Francisco lessingia at this site reflects the early successional development of the restored vegetation there.

(2) *The Battery Caulfield Road site* is a small dune scrub patch (0.4 hectare [1 acre]) that was subjected to early (1988) restoration efforts by the Golden Gate National Recreation Area (National Park Service). A planted Monterey cypress grove partially shades the site to the west and isolates it from Lobos Dunes. The site is heavily invaded by nonnative grasses. It supports a moderate sized colony of San Francisco lessingia, consisting mostly of small plants (P. Baye, pers. observ. 1996-1999, Golden Gate National Recreation Area unpublished data). Population size has been estimated up to 4,800 plants in 1998, increased under management from 873 in 1997. During the 1990's, population size ranged between approximately 2,000 and 6,000 plants (Golden Gate National Recreation Area unpublished data 1998), but declined to 824 plants in 2000 (M. Albert, unpublished data 2001). This population is reintroduced, the product of seeding conducted in 1988 at the approximate location of a historic remnant colony (Golden Gate National Recreation Area

unpublished data). The original colony was probably a subpopulation or daughter colony of the population at the adjacent Lobos Creek site, from which it was severed by the Monterey cypress grove that today covers many hectares of a high, west-facing intact dune slope.

> (3) *The Marine Hospital site*, behind (northeast of) the former Marine Hospital or Public Health Services Building (renamed "Presidio Hills"), is a disturbed remnant stable dune with coast live oak (*Quercus agrifolia*), native and nonnative grassland, and dune scrub vegetation (mostly mock-heather, *Ericameria ericoides*, and coyote-brush, *Baccharis pilularis*). Part of this site had been disturbed by earthmoving activities (a borrow pit for sand and haul road) and trampling, which may have provided or expanded open sandy habitat for San Francisco lessingia here in the past. The site is bordered by a strip of Monterey pine (*Pinus radiata*) to the south and a strip of blue gum trees (*Eucalyptus globulus*) to the east. These tree plantings function as wind-breaks and visual barriers for the adjacent Presidio golf course. San Francisco lessingia is most often associated here with partially bare erosional slopes, remnants of vehicle and pedestrian tracks, annual-dominated sandy flats, and edges of active pedestrian paths along fences — all microsites where vegetation is either low, open, or sparse. The site, now fenced and relatively undisturbed, shows indications of succession toward closed perennial and woody native dune scrub vegetation, as well as colonization by some oak seedlings (P. Baye unpublished data 1998). Recent estimated population sizes (1990's to 2000) usually ranged from 3,000 to 9,000, but surged up to 78,000 in 1998 after intensive weeding (Golden Gate National Recreation Area unpublished data) occupying a variable area around 0.5 hectare (about 1 acre). An undisturbed grove of low-growing native oak woodland and dune scrub borders the west end of the San Francisco lessingia population. A formerly excavated/graded/filled dune area supporting mixed wet meadow and dune slack vegetation (salt rush, *Juncus lesueurii;* Pacific blackberry, *Rubus ursinus*), dune scrub (mostly coyote-brush, *Baccharis pilularis*), and iceplant (*Carpobrotus edulis*) occurs to the north and northwest.

(4) *The Presidio Golf Course roadside site* is a narrow, steep road cut in old dunes on the west side of the maintenance road adjacent to the Presidio Golf Course, across the golf course from the Marine Hospital lessingia site. This area, which covers less than 0.4 hectare (1 acre), is a gap in the narrow stand of blue gum trees that otherwise line the top of the cut and border the golf course. The steep slope undergoes small-scale chronic erosion, and supports a moderate to small population of San Francisco lessingia in the vegetation gaps (ranging from 215 to 8,000 individuals, usually fewer than 2,000; Golden Gate National Recreation Area unpublished data 1998-2001). Dominant vegetation comprises typical native dune scrub dominants, nonnative grasses (primarily *Briza* sp.), and bracken fern (*Pteridium aquilinum*) (P. Baye unpublished data 1998). The site is bounded by the maintenance road, the Golf Course, and blue gum stands, and is parallel to Highway 1. This population is located near Mountain Lake, an historic extirpated locality of San Francisco lessingia.

(5) *The Rob Hill site* is a patch of disturbed, weedy old dune scrub and grassland at the edge of a eucalyptus grove, and adjacent to Battery McKinnon-Stotsenberg. It supports a population of San Francisco lessingia ranging in the thousands of plants. The portion of the site supporting locally abundant dune annuals and San Francisco lessingia covers about 0.4 hectare (1 acre). The site is bounded by a dense grove of blue gums, an evergreen understory of Canary Island ivy (*Hedera canariensis*), and historic military buildings. Population size ranged around 3,000 to 9,000 individuals in the 1990's, but increased to more than 155,000 in 1998 under intensive management (primarily weeding of nonnative annual grasses), and declined to fewer than 500 in 2000. (Golden Gate National Recreation Area unpublished data 1998, M. Albert and P. Holloran, pers. comm. 1998-2001).

(6) *The Wherry Dunes restoration site* is currently a 4-hectare (10-acre) restoration site above the north end of Baker Beach near Battery Chamberlain, located upslope of Lincoln Boulevard at the north end of Pershing Drive. Contiguous with a dune scrub remnant called “Feral Dunes”, this site of demolished buildings has been planted with native

dune scrub vegetation, and a small, volatile founder population of San Francisco lessingia established spontaneously, beginning with a few plants in 1997 (possibly from seed dispersed on footwear and clothing of numerous volunteer restorationists moving between this site and the large, dense population at Lobos dunes; J. Cannon, pers. comm. 1998). The population expanded to several thousand plants spread over a hectare (2.5 acres) in 1999 (P. Baye, pers. observ. 1999) and nearly 25,000 plants in 2000 (M. Albert, unpubl. data 2001).

> Overall annual population size of San Francisco lessingia in the Presidio increased progressively from approximately 21,000 individuals in 1994 to a peak size of over 17 million in 1998 (Golden Gate National Recreation Area unpublished data 1998). Most of this population change was due to the artificial seeding and habitat expansion of the Lobos dunes restoration in an early successional stage. The estimated population size has remained at less than one tenth of the 1998 peak size since then. Other important factors coinciding with the population increase were intensive vegetation management (manual weeding, particularly at Rob Hill) and above-normal rainfall (other than the early dry spring of 1997).

b. Southwestern San Francisco and Vicinity Populations. The historic southwestern San Francisco population included collection localities from the Lake Merced area, probably including areas now within the Fort Funston dune area immediately west of Lake Merced (CAS 3449, *Eastwood* 1913; CAS 166017, *J. T. Howell* 1924; CAS 66038, *J. T. Howell* 1926; Table 1). Collections were also made at Ocean View (DS 593657; *Dudley*, 1899) southeast of Lake Merced where Colma Formation sands occur east of the San Francisco dune sheet (Figure 1). It is not clear whether the “Lake Merced” records were on the east shore area (on Colma Formation sands outside the San Francisco dune sheet), or on dune sands now associated with the modern Fort Funston dunes along the west shore of Lake Merced. No records of San Francisco lessingia are known from the eastern dunes of the city, nor from the extensive mobile dunes of the Sunset district, which persisted well into the 20th century. The Lake Merced and Ocean View populations are now extirpated, last collected there in the late 1920's.

(1) *Hillside Park, Daly City (San Bruno Mountain) population*. The southwestern population of San Francisco lessingia is now represented only by the Daly City population, first reported in 1989 by Elizabeth McClintock (Golden Gate National Recreation Area unpublished files). This population is exceptional geographically and ecologically. It occurs on the western end of San Bruno Mountain on slopes above Hillside Park, below the south face of Reservoir Hill. This location is far south of the main San Francisco dune sheet mapped by Cooper (1967) and Bonilla (1965) (Figure 1 and Figure 6). The sandy substrate is derived from the weakly consolidated and weathered Pleistocene sand deposits of the Colma Formation, a composite of uplifted sands originally deposited in ancient lagoon or estuarine environments. They are weathered and strongly iron-stained (bright yellowish or rusty brown), and include some silt and clay layers (Bonilla 1965, Schlocker 1974).

The origin of the Hillside Park, Daly City population is uncertain. This population may be derived from a local relict population, or it may represent opportunistic modern colonization of regraded sandy slopes, possibly from the former Ocean View-Lake Merced population of southwestern San Francisco. The antiquity of this isolated population is doubtful for several reasons. San Bruno Mountain had been botanized intensively in the early to mid 20th century, but no one reported San Francisco lessingia until recently from an area northwest of San Bruno Mountain, other than the Ocean View collection. Also, the entire population occurs on graded, terraced slopes. The species's center of abundance at the site is on recently excavated and redeposited sand along a utility line, surrounded by older, dense coastal scrub that is unsuitable habitat.

Some of the graded slopes cut in the Colma Formation sands above Hillside Park have subsequently been naturally reworked by wind into dune deposits. The sand here is similar to that of the Fort Funston bluff sediments (mostly Merced formation), which supply much of the parent material for the secondary dunes perched on top of them. These old iron-stained yellowish sands contrast with the gray to tan recent Holocene

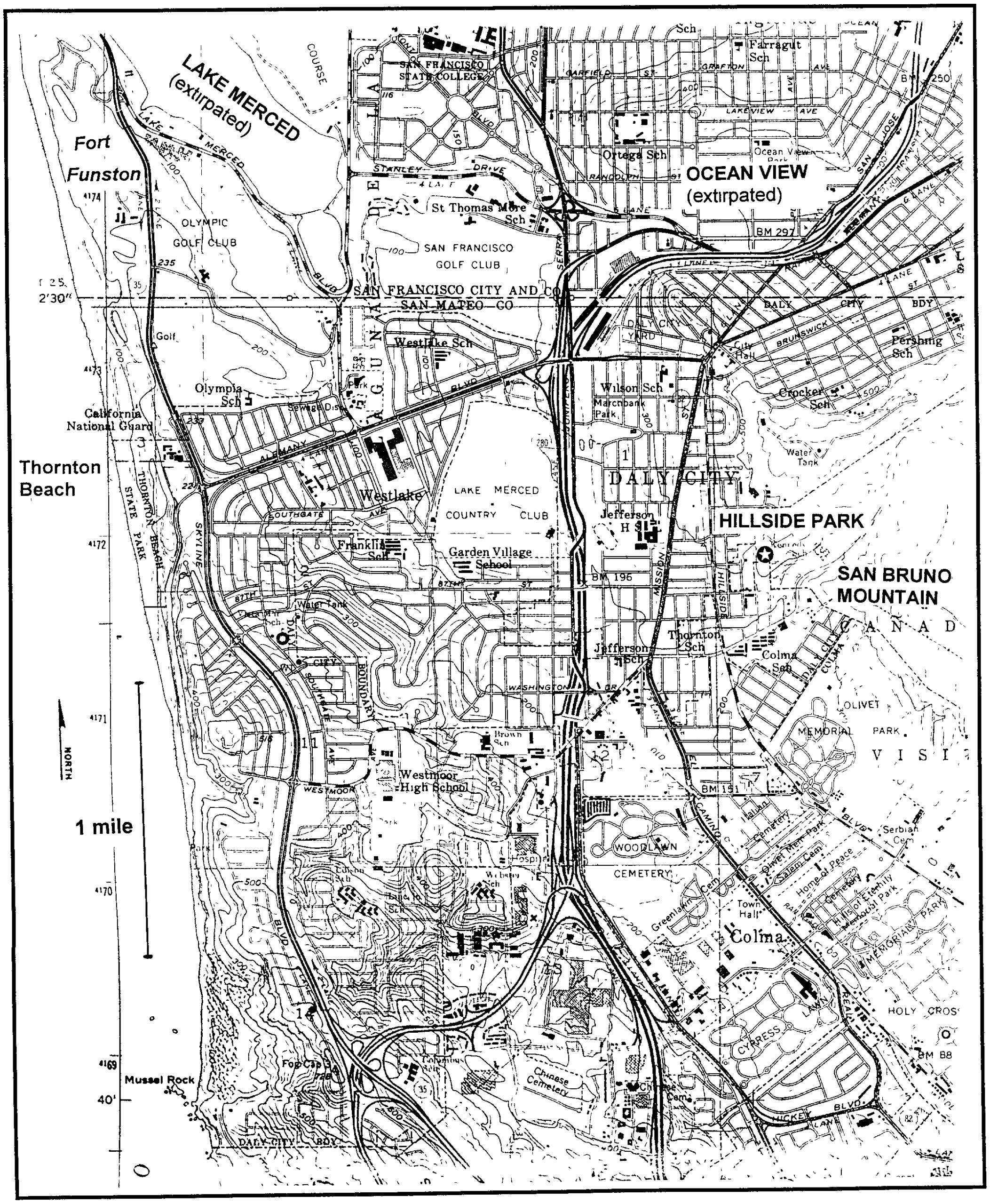


Figure 6. Approximate contemporary location of San Francisco lessingia (*Lessingia germanorum*) at Hillside Park, Daly City. Circled star indicates approximate location of San Francisco lessingia colonies.

sands of the San Francisco dune sheet. The Hillside Park sand slopes support coastal scrub vegetation that is essentially similar to the dune scrub of San Francisco, particularly the Sunset Heights dune remnants (Hawk Hill, Sunset Heights Park, Grandview Park) and Fort Funston dunes (P. Baye unpublished data 1998).

The Hillside Park slope population of San Francisco lessingia extends from the top of the east-facing slope at the end of Bismarck Street to the end of the south-facing slope near Price Street and the Kennedy School, above Bonnie Street (Figure 6). It is the largest of the "natural" (not deliberately restored or seeded) remnant populations in terms of population size and area, exceeding even the Rob Hill site. The highest densities of San Francisco lessingia in 1999 occurred in the vicinity of a seep and willow grove near a buried utility line alignment leading to the crest of Reservoir Hill from the corner of Bonnie and Lausanne streets. The roughly linear high-density strip of San Francisco lessingia and dune annuals probably tracks the footprint of past grading activities along the buried pipeline alignment. Low densities (scattered individuals and small colonies) occur near the summit of a weedy east-facing slope near blue gums, iceplant, and residential back yards on Wynadotte Street (as far south as Bismarck Street); and on the graded, terraced slope above Bonnie Street (P. Baye unpublished data 1998). The population occurs on both private land and municipal lands of Daly City. Portions of the site have been maintained in recent years by citizen volunteers using manual removal methods to control invasive nonnative vegetation (S. Smith, pers. comm. 1998).

c. Variation in Abundance of San Francisco Lessingia. Population sizes of the various San Francisco lessingia sites have fluctuated extremely since they have been observed during the last two decades, apparently in response to factors such as drought, mechanical disturbance, artificial seeding (augmentation and reintroduction), weeding activities, and competition with weeds. In 1980, the single population then known (now within the Lobos Dune site) included only 250 plants. The population decreased to 19 plants in 1985, the most extreme population "bottleneck" since monitoring began. Population size rose to around

900 in 1986, and declined to approximately 600 in 1989 (Golden Gate National Recreation Area file information). In 1994, after years of improved weed management efforts and discovery of additional local populations, the cumulative Presidio population approached an estimated 20,000 plants. In 1998, after 2 years of restoration at Lobos Creek Dune site (involving extensive tree removal, grading, and direct seeding of disturbed sand), overall population size of San Francisco lessingia in the Presidio (total of all sites) peaked at roughly 17 million; the current population size as of 2001 is under 2 million (M. Albert, unpubl.data 1998-2001). In 1989, only 310 plants were known from the Hillside Park site. In 1998, the population above Hillside Park was at least an order of magnitude larger than the 1989 estimate (P. Baye unpublished data 1998).

The overall rangewide number of San Francisco lessingia plants, though highly fluctuating and quantified with variable accuracy and precision, ranges over a magnitude around 500,000 to 2,000,000 plants. Population size and population trends are sensitive to habitat conditions, particularly the availability of sparsely vegetated to bare sand within dune scrub and grassland. The species is distributed over seven relatively discrete populations, with the largest (core) population at the restored Lobos Dune site.

3. Ecology and Reproduction

a. Environmental Conditions. Modern populations of San Francisco lessingia have high fidelity to vegetation gaps in stabilized old sand dunes or sandy soils derived from ancient sandy coastal deposits. San Francisco lessingia is now narrowly associated with either sparse vegetation cover or substantial vegetation gaps, usually related to past artificial disturbance of the substrate or the vegetation. Historic populations were probably associated with early stages of succession following natural dune blowouts, or other local disturbances within coastal dune scrub. The species may also have occupied stable dune vegetation kept sparse or open by nutrient or drought stress. Spence (1964) observed that annual *Lessingia* species were typical of dry, open, and somewhat disturbed habitats, occurring in small, dense, disjunct populations. Nearly all historic collections of San Francisco lessingia with specific locality and habitat information have been made in areas with disturbed dune deposits. Exceptions include one collection (*Raven* [1954], CAS 491875, Table 1) that was obtained from weak, eroding sandy bluffs (Colma Formation), and the historic Ocean View locality (Table 1; *Dudley* [1899]), which is mapped as Colma Formation sands as well (Bonilla 1965). The Hillside Park (Daly City) population also occurs on Colma Formation sand deposits that have been disturbed and are subject to reworking by wind and runoff erosion. There are no historic or modern records of San Francisco lessingia occurrence in foredunes or similar youthful dune areas with little or no soil development and strong dune mobility.

Undisturbed areas of dune scrub or nonnative grassland with high density and cover of vegetation show little tendency to become invaded by San Francisco lessingia, even when they are adjacent to source populations of this species (P. Baye, pers. observ. 1997-1998). In contrast, San Francisco lessingia can spread vigorously under favorable climate conditions when extensive substrate disturbance occurs. After dune restoration sites at Lobos Creek and Wherry dunes were graded, the low density and cover of vegetation encouraged rapid spread of San Francisco lessingia from 1997-1998 (J. Cannon, pers. comm. 1997, Golden Gate National Recreation Area unpublished data 1998). Within San Francisco lessingia populations at Lobos Dunes and behind the former Marine Hospital, plant size and fecundity appear to increase markedly at the edges of vegetation gaps, such as footpath margins, where potential competition is reduced (P. Baye, pers. observ. 1998). The species is intolerant, however, of even a few centimeters (an inch or less) of active sand accretion during its seedling, juvenile, and mature developmental phases (Pogge 1998).

Based on modern and historic evidence, it appears likely that in prehistoric conditions San Francisco lessingia was a sporadic local colonist of secondary blowouts during their restabilization phase, or around their vegetated margins. San Francisco lessingia probably persisted at sites where dune scrub and grassland vegetation remained sparse or open, especially with patches of exposed but relatively immobile bare sand. Analogous habitat conditions can be observed today in relatively small secondary blowouts within well-stabilized portions of large dunes on the central California coast. In the stabilizing phases of secondary blowout succession, when bare sand begins to stabilize under the influence of recolonizing plants, vegetation cover is sparse and low, but prevailing rates of sand accretion or deflation are also reduced to low levels (P. Baye, pers. observ. 1990-1999). San Francisco lessingia would likely have been an element of this vegetation, and probably persisted around wind-scarped edges of blowout crests where chronic, low-level erosion gaps were sustained. Under modern conditions, disturbances such as trampling, earthmoving, and grading probably serve as surrogates for dune blowouts.

b. Plant Associations. San Francisco lessingia is associated with a diverse range of species typical of dune scrub and grassland in San Francisco, as well as many nonnative species (Appendix I). Spence (1964) observed that *Lessingia* species are generally unable to grow and compete where the associated vegetation is dense. Accordingly, some associations between San Francisco lessingia and other species (particularly shrubs) are likely to be antagonistic at small spatial scales. However, positive correlations may be expected with herbaceous species with similar life-history, low growth habit, or colonizing traits, which occupy vegetation gaps and blowouts between patches of dense shrubby vegetation. Low-growing herbaceous species associated with San Francisco lessingia today include dune gilia (*Gilia capitata* ssp. *chamissonis*), San Francisco spineflower (*Chorizanthe cuspidata*), dune evening-primrose (*Camissonia cheiranthifolia*), annual dune evening-primroses (*Camissonia micrantha* and *Camissonia contorta*), annual plantain (*Plantago erecta*), coast fiddleneck (*Amsinckia spectabilis*), sand mat (*Cardionema ramossisima*), dune popcorn-flower (*Cryptantha leiocarpa*), and annual phacelia or wild heliotrope (*Phacelia distans*).

Dune shrub species are probably positively associated with San Francisco lessingia at a coarse scale (large sample areas with shared overall habitat), but negatively associated with it at a small scale (different microenvironments within habitats). Relatively tall or coarse perennial herbaceous plant species associated today with San Francisco lessingia (possibly in later stages of succession) include dune goldenrod (*Solidago spathulata*; Daly City only today), California phacelia (*Phacelia californica*; Daly City only today), yarrow (*Achillea millefolium*), bracken fern (*Pteridium aquilinum*), and California poppy (*Eschscholzia californica*). Growth, survivorship, and reproduction of San Francisco lessingia at the Presidio are inhibited by competition from nonnative grasses, particularly ripgut brome, *Bromus diandrus* (Pogge 1998). San Francisco lessingia also occurs with other invasive nonnative annual weeds such as foxtail (*Vulpia bromoides*), horseweed (*Conyza canadensis*), and wild oat (*Avena fatua*) (P. Baye, pers. observ. 1997-1998).

c. Life History and Reproduction. Seedlings of San Francisco lessingia emerge from late fall to spring, soon after periods of rainfall and increased near-surface sand moisture (Pogge 1998, J. Cannon, pers. comm. 1996). Seedlings emerging at different times and growing at different rates form a size hierarchy. Individuals that emerge and achieve large size earlier in the growing season have higher reproductive output (Pogge 1998). There are two marked growth phases in development (Howell 1929). During the rainy season seedlings develop into juveniles, which are unbranched vegetative short plants (Figure 4), typically with basal rosettes (relatively broad leaves on short erect stems with the growing tip near the ground). Around the end of the rainy season (mid- to late spring) the erect central shoot of the juvenile plants elongates, then branches profusely, producing smaller leaves. The plant develops a low, spreading, bushy growth habit in open conditions before it enters reproductive phase (Figure 4, Howell 1929, Pogge 1998). Branching continues repeatedly after flowering and seed set. Lateral shoots develop below individual flowerheads and seedheads, terminating in new clusters of flowerheads. These flowerheads in turn develop more lateral shoots below them, enabling flowering and seed production to occur continuously together to almost to the end of the life-cycle (P. Baye, pers. observ. 1998).

Flowerheads begin to form as early as May; unopened flowerheads are common in early summer. Flowers usually open beginning in mid- to late summer, with abundant flowering in August-September, continuing through November (Howell 1929, Pogge 1998). Reproductive output of individual plants is highly variable. Pogge (1998) found a range from 1 to over 1,400 flowerheads per plant, depending on plant size. Large plants in sparsely vegetated areas may produce many hundreds of flowerheads, each bearing up to 40 florets (potential seeds; Lane 1993), but actual average number of seeds per flowerhead is about 26 (Pogge 1998), implying that the largest individuals may produce up to 36,400 seeds. Individuals competing with dense nonnative annual grasses may be very short and sparsely branched, with few or tens of flowerheads.

Spence (1964) performed artificial hybridization experiments with many *Lessingia* species, and determined that *Lessingia* species are generally self-incompatible (infertile when restricted to self-fertilization). Sibling plants grown in isolation from parent populations sometimes fail to produce viable seed despite availability of potential pollinators (P. Baye, pers. observ. 1998), which suggests that self-incompatibility may limit natural establishment of isolated small founder populations established from infrequent long-distance dispersal events. Artificial interspecific hybrids develop rather easily in cultivated populations (Spence 1964). Natural interspecific hybrids of San Francisco lessingia, however, would not be expected to occur because the species is geographically isolated from other species in the genus (Spence 1964).

Pollination may be achieved by insects, or possibly by wind as well (Spence 1964). Pollen of *Lessingia* species is light and dry (Spence 1964) rather than heavy and sticky, as would be expected for flowers exclusively adapted to insect pollination (Faegri and van der Pijl 1979, Proctor *et al*. 1996). Some wind-pollinated grassland species are also pollinated by insects (Faegri and van der Pijl 1979). Spence (1964) failed to detect any indication of pollen transfer by insects in any wild populations of *Lessingia* species, even though potential pollinators (Diptera and syrphid flies, which lacked detectable pollen traces on their bodies) were present. Other potential insect pollinators observed visiting *Lessingia germanorum* flowers include numerous moths and butterflies (order Lepidoptera), such as snout-nosed moths (family Pyralidae), skippers (Hesperidae), ringlets (Satyridae), cabbage whites (Pieridae, *Pieris rapae*), blues and hairstreaks (Lycaenidae), and American Ladies, (Nymphalidae, *Vanessa virginiensis*); flies (order Diptera); bees and wasps (Hymenoptera), including sand wasps (family Sphecidae), sweat bees (Halictidae), andrenid bees (Andrenidae), bumblebees (Apidae, *Bombus vosnesenskii*); plant bugs (order Hemiptera, family Miridae); and weevils (order Coleoptera, family Curculionidae) (A. Whelchel unpublished data 1998).

Ripe achenes (plumed "seeds") begin to disperse in September and continue through late fall. Earliest achenes have been observed in late June (Pogge 1998). Achenes are primarily wind-dispersed, as indicated by their light weight, small size, and well-developed pappus (Spence 1964). Seed set of populations at the

Presidio appears to be consistently high (P. Baye, pers. observ. 1996-1998). Seed dispersal distance has not been studied, but seedling distribution tends to be contagious around parent plants. Landscape barriers to dispersal, such as tree plantations, may be more significant barriers to dispersal than inherent dispersal ability of achenes. Seeds may also possibly be passively dispersed by humans, by adherence of seed to footwear or clothing (J. Cannon, pers. comm. 1997). While dispersal ability of San Francisco lessingia may be low because of landscape and habitat constraints, its colonizing ability in suitable open or disturbed sandy vegetation gaps (e.g., Hillside Park, Lobos Dunes, Wherry Dunes) appears to be quite strong.

San Francisco lessingia is easily cultivated and shows no special requirement for soil composition (Spence 1964). Germination also occurs without difficulty in cultivation. Seeds lack innate, physiological dormancy (Spence 1964). Seeds germinate very near the sand surface; as little as 1 to 2 millimeters (less than 0.08 inch) of sand burial strongly inhibits germination (Pogge 1998). Stored seeds retain viability for at least 5 years with only a 50 percent reduction in the ability to germinate; 2-year-old seed can exhibit 95 to 100 percent germination (Spence 1964). These germination data suggest that at least a short-lived soil seed bank is likely to occur in nature, but the long-term viability of soil seed banks for this species is unknown. The long-term viability of artificially stored refrigerated seed is also unknown. Mollette (1998) concluded that San Francisco lessingia formed only a transient seed bank, based on relatively short-term (2 years) field data. Germination in cultivation occurs within 3 or 4 days after sowing and watering, with a few seeds germinating as long as 127 days later (Pogge 1998). Seed sown in newly restored dune habitat in years of high rainfall resulted in high seedling establishment (J. Cannon, pers. comm. 1997). Germination rate is unaffected by the presence of ripgut bromegrass under experimentally manipulated field conditions. Germination percentage in cultivation may reach nearly 90 percent, and germination percentage in the field has been observed from over 43 to nearly 47 percent (Pogge 1998).

4. Causes of Decline and Threats to Survival

San Francisco lessingia was listed as threatened (U.S. Fish and Wildlife Service 1997) based on an analysis of the five factors under section 4(a)(1) of the Endangered Species Act: 1) the present or threatened destruction, modification, or curtailment of its habitat or range (urbanization, invasion of alien plants, sand quarrying, bulldozing, and damage by pedestrians, bicycles, and off-road vehicles); 2) overutilization for commercial, recreational, scientific, or education purposes (possible future threat); 3) disease or predation (no known threat); 4) the inadequacy of existing regulatory mechanisms (limited protection from State law and National Park Service land management); and 5) other natural or manmade factors affecting its continued existence (bicycles, pedestrians, off-road-vehicles, garbage dumping, fertilizer-contaminated runoff, and habitat fragmentation).

Habitat loss and adverse alteration of ecological processes are the principal historic causes of decline of San Francisco lessingia. The resulting small numbers and localized distribution of the species have in themselves become a primary threat to survival because of the amplified risk of extinction through random catastrophic events or progressive vegetation change. Other threats identified above are relatively more localized or secondary, dependent aspects of the dominant threat of habitat loss and degradation.

The initial historic cause of decline in the abundance and distribution of San Francisco lessingia was the conversion of patchy dune scrub habitat to conifer plantations, military posts, residential development, golf courses, and other urban land uses. These conversions began at a significant scale quite early, around the mid-19th century, and reached their maximum extent around the 1950's and 1960's when the last large tracts of privately owned undeveloped lands in San Francisco were urbanized (Kaufeldt 1954). Land use conversion reduced population size and distribution of dune plants to small remnants. These small remnants were isolated from natural processes that may have maintained stand dynamics, particularly secondary dune blowout succession (spontaneous initiation, enlargement, and later revegetation of bare, wind-eroded patches in sand dunes).

The essential ecological processes that have been lost in San Francisco dune vegetation are unimpeded transport of sand from beaches and mobile dune complexes, and natural disturbances at both large and small scales that controlled vegetation gap dynamics. Other essential ecological and geomorphic properties of the San Francisco dune system that have been lost or diminished significantly include variation in dune topography, which controls windflow patterns and intensity (Olson 1958); burial and rejuvenation of stabilized dunes and dune slacks (wet depressions) by mobile dunes; wind erosion and sand transport in dune blowouts; and sand slope adjustment in eroding dune scarps (Jungerius *et al*. 1981, Carter 1988, Gares and Nordstrom 1990, Fraser *et al*. 1998). These properties are typical of dune systems with complex vegetation mosaics associated with development of blowouts. Blowout dynamics and associated vegetation patterns develop over large spatial scales and appropriate landscape positions, but not in small, isolated dune remnants within a sheltering matrix of buildings and planted stands of nonnative trees. Homes and tree plantings create obstacles to sand transport and create wind-shadows, reducing wind velocities and potential sand transport corridors in remnant dune vegetation. They also eliminate potential sand fetch areas — alignments along which dominant winds may sweep sand to deposit downwind. These influences tend to promote stabilization of small dune remnants, and encourage relatively complete closure of dune scrub vegetation. Without recurrent disturbances and regeneration of vegetation gaps, and the characteristic physiological stresses of coastal dunes that maintain integrity of the vegetation character, the long-term persistence of San Francisco lessingia colonies is unlikely.

The artificial stabilization of dunes in San Francisco, and an artificial reduced disturbance regime in the dune remnants, would probably have caused extinction of San Francisco lessingia if local artificial disturbance had not partially compensated for them. Occasional earthmoving, grading activities, creation of oversteepened erosional slopes, vehicle tracks, trampling, and other disturbances caused by humans probably acted as surrogates for natural disturbances, and maintained sandy vegetation gaps in coastal dune scrub that enabled San Francisco lessingia to survive in small and unstable remnant patches for many decades. When populations of San Francisco lessingia were relatively large and well-distributed, artificial disturbances caused by humans were probably beneficial to the survival of the species in altered remnant dune habitats. Disturbances within excessively small habitat remnants, however, may be detrimental to the persistence of San Francisco lessingia today. Disturbances that would otherwise be beneficial may jeopardize remnant populations that are already precariously small. Whether disturbances are beneficial or harmful to remnant populations depends on the scale of disturbance relative to population size and distribution. Artificial disturbances are probably beneficial to San Francisco lessingia when they are intermittent and patchy within an extensive population. If disturbances are relatively frequent, chronic, or widespread, they are likely to become detrimental to regeneration of small populations or small habitat patches.

The secondary cause of decline, and the most important short-term threat to survival of San Francisco lessingia, is habitat change caused mainly by the spread of invasive nonnative vegetation, but also by excessive density and cover of native woody shrub species, especially in sheltered conditions (such as planted groves of evergreen trees). The principal nonnative invasive plants in older, stabilized San Francisco dunes are iceplant (*Carpobrotus edulis* and its hybrids; Vila and D'Antonio 1998), and annual Mediterranean grasses (in particular ripgut brome, *Bromus diandrus*). Other species that are locally aggressive and colonial invaders of stable dunes and sandy urban soils include an annual iceplant (*Conicosia pugioniformis*); Bermuda-sorrel (*Oxalis pes-capreae*); and a relatively recently established South African grass (*Ehrharta erecta*) (Appendix III). Species like iceplant and ripgut brome tend to produce continuous, dense stands that lack vegetation gaps and accumulate surface plant litter and soil organic matter. These conditions apparently discourage regeneration of San Francisco lessingia.

Introduced trees from plantings in former dunes (Monterey cypress, *Cupressus macrocarpa*; Monterey pine, *Pinus radiata*; blue gum, *Eucalyptus globulus*; Appendix III) also spread spontaneously into dune scrub over time, and may gradually convert dune scrub remnants to nonnative "forests." Stands of nonnative trees, whether planted or naturalized, have significant indirect impacts as well; the wind-shadows of tall nonnative tree groves also further diminish the possibility of natural disturbance regimes (dune blowout and slope dynamics) from reestablishing, even in dune restoration sites. They can also rapidly reverse potential gains in species recovery by degrading the quality of restored dune habitat for San Francisco lessingia. Trees induce fog-drip moisture inputs to soil, and tree canopy shading reduces evapotranspiration rates of the ground layer vegetation. Fog drip and shade from trees reduce moisture stress that would naturally exclude many shrubs and herbs from dune vegetation, and can promote dense herbaceous undergrowth or dense mats of leaf litter even beyond their drip-lines, apparently inhibiting growth and spread of San Francisco lessingia (P. Baye, pers. observ. 1996-1999).

Potentially beneficial disturbances of San Francisco lessingia habitat may nonetheless harm some existing populations, especially small ones. Trampling, off-road bicycle or other vehicle use, small-scale sand quarrying, and burrowing by dogs had been identified as threats to the species' survival in the 1980's and early 1990's (U.S. Fish and Wildlife Service 1997). In the Presidio, these impacts are proportionally smaller today because of expanded habitat area, increased public education, restricted pedestrian access to sensitive vegetation, and symbolic fencing (fencing that is easily defeated physically, but defines areas of restricted access). If the Golden Gate National Recreation Area is unable to maintain dune vegetation quality, or becomes unable to adequately regulate trampling impacts, these disturbances could again become significantly detrimental to some colonies of San Francisco lessingia.

Small population size, small habitat patch size, and fragmentation (isolation) of habitat patches in the urban landscape are indirect effects of habitat loss and degradation, but they are now also probably independent threats to the survival of San Francisco lessingia. When there are few suitable habitat patches and seed dispersal distances to the patches are relatively large, local extinction of San Francisco lessingia becomes likely. Population failure may also occur when infrequent opportunities for new colonization (formation of sparse or bare patches) are not favorably synchronized with local extinction of small colonies. Turnover of local colonies in dynamic patches is possible when there are numerous, well-distributed populations within efficient dispersal distance of each other (White 1996). In theory, such turnover would result in dynamically stable populations, involving the local extinction of some patches, roughly balanced by spontaneous establishment of new colonies in recently-disturbed sites.

Dynamically stable populations of San Francisco lessingia do not remain near an "average" population size but instead may fluctuate strongly over short time scales (ca. 3 to 7 years). For this reason, fixed population size targets have limited applicability for San Francisco lessingia.

Amelioration of natural environmental stresses inherent in coastal dunes (e.g., soil moisture deficiency, soil nutrient deficiency, high evapotranspiration rates, and mechanical wind-stress) is also likely to be detrimental to long-term survival or recovery of San Francisco lessingia. Reduction of environmental stress or enrichment of plant resources (nutrients, moisture) tends to increase growth and density of vegetation, particularly weedy vegetation. Although San Francisco lessingia individuals may grow well in such favorable environments, the species is unable to regenerate well in dense vegetation. Therefore, addition of irrigation or fertilizer to dune soils for landscape improvements, or shading and fog-drip caused by planting of nonnative trees, tend to be antagonistic to annual dune herbs like San Francisco lessingia. Allowing nonnative tree seedlings to establish in open sandy areas would have similar detrimental effects on soil suitability for San Francisco lessingia. In the long term, addition of any water, nutrients, or organic soil amendments in restorable potential San Francisco lessingia habitat within Presidio landscapes could result in effectively irreversible soil conditions (or conditions costly or difficult to reverse) that are unfavorable for San Francisco lessingia's recovery. Landscape maintenance or enhancement is a potential conflict in some Presidio settings where restorable habitat exists.

The recent transfer of Golden Gate National Recreation Area lands of the Presidio (other than the immediate coastline) to the Presidio Trust, a wholly owned government corporation (16 U.S.C. § 460 bb appendix), has unclear implications for the recovery of San Francisco lessingia. The Presidio Trust is currently developing and leasing lands within the Presidio for commercial use (K. Feyerabend, pers. comm. 1998). Landscaping for new or renovated buildings could include ornamental plants or new weeds that could invade San Francisco lessingia populations; trees that act as windbreaks, fog-drip collectors, or shade sources; or use of irrigation, mulches, or fertilizer. These landscaping features could indirectly affect San Francisco lessingia populations, habitat quality, or habitat restoration potential. Development or infrastructure improvement of areas in the Presidio with highly restorable former dune soils might impede or reduce the potential for full recovery of San Francisco lessingia, particularly where the lessingia is near sites with high potential for re-use (e.g., Marine Hospital, Wherry Housing) or improvements and expansion (e.g., golf course).

The legislation authorizing the Presidio Trust also mandates the transfer of Presidio Trust lands to the General Services Administration (GSA) for "disposal" (allowing for the possible transfer to private ownership, rather than reversion to the National Park Service) if financial success criteria of the Trust are not met after a specified period of time. This impetus to meet financial criteria may increase pressure to redevelop lands of the Presidio, and could limit the availability of land needed for dune restoration for recovery of San Francisco lessingia. If financial objectives of the Presidio Trust are not met, disposed "privatized" lands could also significantly reduce opportunities for habitat restoration and reintroduction of San Francisco lessingia. Disposal of Federal lands to non-Federal jurisdiction would effectively remove much of the legal protection for San Francisco lessingia and its habitat in the Presidio. These two threats are not mutually exclusive, and could compound the loss of restorable habitat otherwise available for recovery of the species.

Urban development of private lands (particularly the sandy steep slopes above Bonnie Street, Daly City) could impede conservation of the Hillside Park population of San Francisco lessingia. Residential development of the sand slopes in the area would directly eliminate habitat and increase demand for artificial stabilization (and thus habitat loss) on undeveloped portions of the habitat. Urban runoff and subsurface seepage of fertilizer-contaminated irrigation water may promote growth of dense vegetation (native or nonnative), which is incompatible with persistence of dry, sparse, open San Francisco lessingia habitat. Further fragmentation and reduction in size of this small habitat patch would diminish its potential long-term viability by reducing potential number and size of subpopulations, reducing potential insect pollinator refugia, and increasing urbanized edges.

Other potential threats, such as overcollection (amateur or scientific destructive sampling), herbivory, pests, and diseases appear to have been negligible or minor contributors to the decline and endangerment of San Francisco lessingia. Loss of adaptive genetic variability is often a concern for some endangered species that are artificially reduced to small, isolated populations, although there is only limited evidence that colonization or persistence of plants are related to genetic variability (Barrett and Kohn 1991). Demographic and environmental factors may be more important than genetic factors in determining viability of most plant populations (Guerrant 1992, Nunney and Campbell 1993). Even though San Francisco lessingia has been reduced to very small populations in the recent past, it appears to have remained adaptable enough to exploit new and altered habitat vigorously, as indicated by very rapid population growth following habitat restoration. The prevalence of high seed production in all remnant and expanded populations (J. Cannon, pers. comm. 1997; P. Baye, pers. observ. 1998) suggests that pollinator limitation or low fertility (such as mating compatibility problems) have not recently been significant contributors to the species' decline. Habitat loss and degradation have been the main threats to the species.

5. Conservation Efforts

Brian O'Neill, General Superintendent of the Golden Gate National Recreation Area, National Park Service petitioned the U.S. Fish and Wildlife Service under the Endangered Species Act to emergency-list San Francisco lessingia as endangered on May 28, 1991. We proposed to list San Francisco lessingia as endangered on October 4, 1994. The final listing of the species as endangered was published June 19, 1997 (U.S. Fish and Wildlife Service 1997). San Francisco lessingia was also listed as endangered by the State of California in 1990 (California Department of Fish and Game 1992). The recovery priority number for San Francisco lessingia is 2C, indicating a species that has a high degree of threat and high recovery potential and is in conflict with construction or other development projects (see criteria published by *Federal Register* Notice [48 FR 43098; September 21, 1983]).

Important conservation efforts for the survival of San Francisco lessingia during the last 20 years include suppression of nonnative invasive weeds; protection against destruction of populations by mowing, sand quarrying, and grading; protection against development; habitat restoration and expansion; population augmentation (seeding into restored habitat); annual monitoring; and land use planning that preserves opportunities for habitat restoration and reintroduction. Conservation efforts by local citizens and conservation organizations prior to and after listing of San Francisco lessingia were critically important to the species' survival. They included labor-intensive recurrent manual weeding; lobbying landowners and municipal governments in Daly City to avoid severe short-term impacts to remnant populations; and lobbying for long-term land use planning in the Presidio compatible with conservation of the species (U.S. Fish and Wildlife Service file information 1989-1990; J. Cannon, P. Holloran and S. Smith, pers. comm. 1997-1998). Daly City has been responsive to citizen requests to avoid impacts from maintenance activities, and has cooperated with citizen-led manual weeding activities (S. Smith, pers. comm. 1998). Daly City and private landowners have also practiced benign minimal vegetation management of sandy slopes that have supported San Francisco lessingia. More aggressive slope stabilization plantings would potentially have eliminated the population.

The Golden Gate National Recreation Area (National Park Service), following the closure of the Presidio as a military facility, has led the conservation of San Francisco lessingia. The Golden Gate National Recreation Area has established site stewardship programs aimed at coordinating volunteer labor to control nonnative vegetation at Presidio population sites. In cooperation with the nonprofit Golden Gate National Parks Association, it has significantly expanded habitat (dune scrub) and population size of San Francisco lessingia at the Lobos Dune restoration area from less than 0.2 hectare (0.5 acre) with a small colony to approximately 5 hectares (13 acres) supporting an extensive, vigorous population. This restoration anticipated recovery actions in this plan, and will contribute substantially to the recovery of the species, assuming appropriate vegetation management is sustained. The Golden Gate National Recreation Area has also monitored population sizes of San Francisco lessingia over time and fenced off remnant populations on the Presidio to protect them from excessive trampling. Joint, cooperative stewardship (weeding) programs run by the Golden Gate National Recreation Area and the ParksAssociation have improved habitat quality of San Francisco lessingia sites. The Golden Gate National Recreation Area has also facilitated and permitted graduate student research on San Francisco lessingia populations, providing important basic biological information on pollination ecology and plant interactions.

The San Bruno Mountain Habitat Conservation Plan, adopted in 1983 under section 10(a)(1)(B) of the Endangered Species Act (U.S. Fish and Wildlife Service permit PRT 2-9818, expiring March 31, 2013) before San Francisco lessingia was federally listed as endangered in 1994, does not include or otherwise protect the Hillside Park, Daly City site that supports San Francisco lessingia.

6. Species Recovery Strategy for San Francisco Lessingia

The recovery strategy for San Francisco lessingia is based primarily on protecting and expanding the existing populations within native coastal dune scrub vegetation, followed by active reintroduction and expansion of San Francisco lessingia in unoccupied, restored or enhanced habitat within its historic range. Neither protection of existing populations nor restoration and reintroduction projects would alone be sufficient to recover the species in the long term. Merely maintaining the existing relict populations, which are surrounded by degraded vegetation that has been invaded by nonnative species, would risk failure in the long term. Management of small remnant populations within extremely reduced habitat fragments would be equivalent to mere cultivation of the species. Maintenance of small relict populations in the foreseeable future, however, will provide interim insurance against extinction. These populations can be used as sources of stock for reintroduction in dune restoration projects.

The best chance for recovery of a species with highly reduced natural habitat remaining is through jointly protecting existing populations and establishing restoration/reintroduction programs for the species recovery (Falk 1992). Restoration and reintroduction depend heavily on unpredictable chance events in changing environments — uncertainties that are inherent in restoration of dune vegetation and establishment of founder populations (Kutner and Morse 1996, White 1996). Restoration and reintroduction projects for San Francisco lessingia may have less predictable success than intensive maintenance of relict individual populations in static conditions, but they also have much higher potential long-term “yield” for dynamically stable populations that may be less dependent on chronic manipulation. Successfully restored San Francisco lessingia populations and dune communities also are more likely to exhibit natural ecological diversity that can shape ongoing evolutionary processes affecting the species.

Recovery of San Francisco lessingia requires that appropriate vegetation composition, structure, and dynamics be established and maintained on suitable dune topography. In particular, areas of diverse dune topographic relief and exposure are needed for a mosaic of dune scrub and patches of bare or sparsely vegetated dune sand (blowouts) in various stages of recolonization by native dune scrub vegetation. These ecological requirements are analogous to those proposed for managing biological diversity of some noncoastal dune systems (Lesica and Cooper 1999). The ecological and physical processes that maintain these features operate only at relatively large spatial scales compared with the small remnant patches of San Francisco lessingia at the time of listing. Thus these processes require at least some large sites (many tens of acres in suitable configuration and topography) with suitable exposure, aspect, sand supply, slope, and disturbance agents. Nearly all of the reserves proposed for the species' long-term recovery (see below) meet this need.

The conceptual site-specific designs of San Francisco lessingia reserves within three recovery units (see Chapter IV, Comprehensive Strategy of Recovery Actions, San Francisco lessingia recovery), were based on localities of historic or relict populations, suitable restorable substrate, landscape position, and feasibility of restoration and protection (landscape constraints). Reserve design was also influenced by basic ecological understanding of dune systems in the central California coast region, and limited historical information on San Francisco's former dunes. Recovery objectives for San Francisco lessingia focus on three main geographic recovery units. The main recovery units (Figure 7) are: (1) the Presidio Recovery Unit, including the northern cluster of populations in restored dune complexes within the Presidio (Lobos-upper Baker Beach-Wherry-Marine Hospital area); and (2) the Southern Recovery Unit, including a southwestern pair of reserves at Hillside Park (Daly City) and a large population at restored Fort Funston dunes. Hillside Park and Fort Funston together comprise the Southern Recovery Unit. A third subsidiary recovery unit, comprising smaller satellite

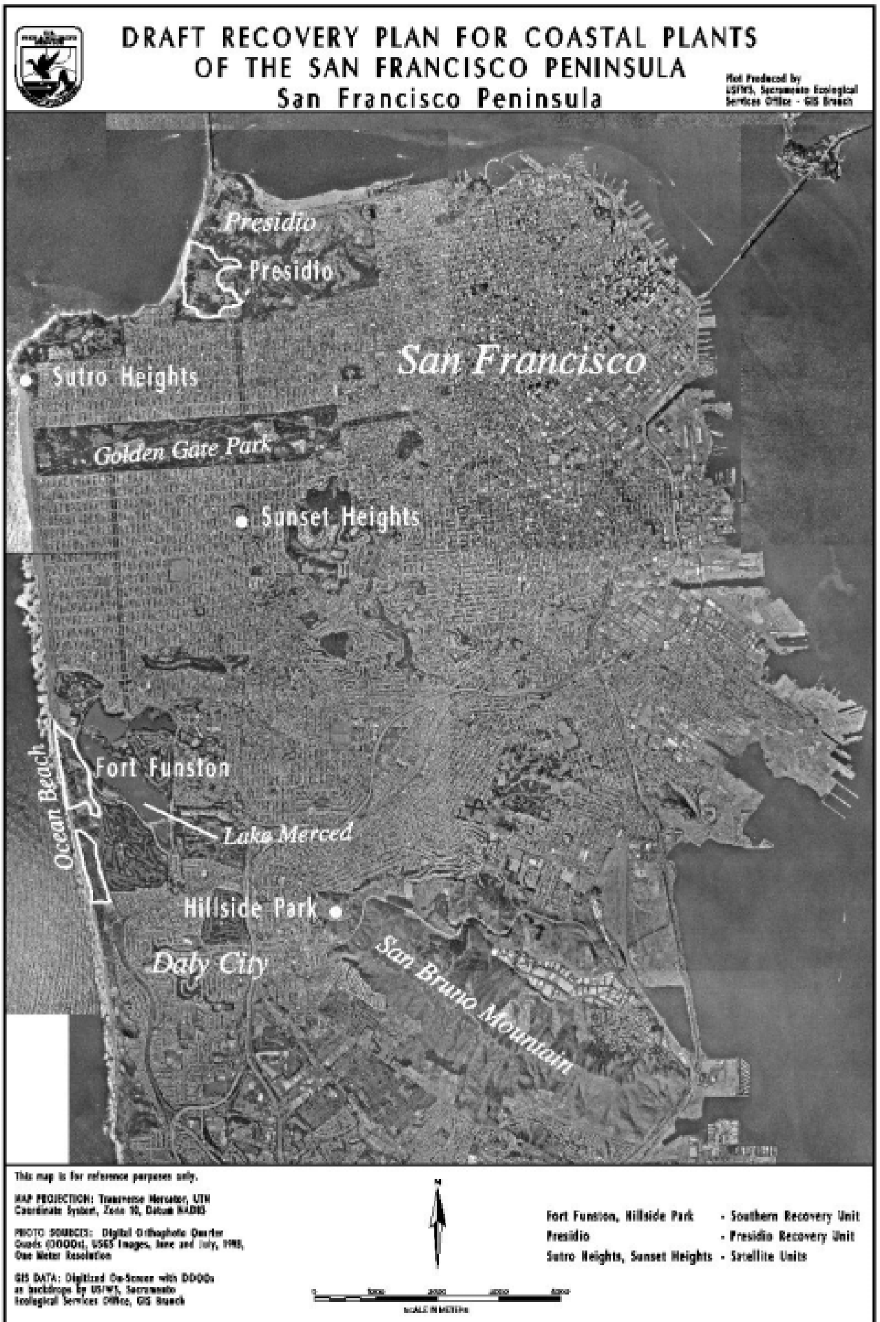


Figure 7: Distribution of Recovery Units for San Francisco Lessingia (*Lessingia germanorum*) on the San Francisco Peninsula.

populations rather than larger core populations and reserves, includes reintroduced populations at remnant dunes of Sunset Heights and Sutro Heights near the Cliff House (Figure 1). These sites are within the historic geographic and ecological range of the species, but are not among the few specific historic San Francisco collection localities for which site-specific names were attributed prior to urbanization of western San Francisco. They are, however, among the only sites available with potential restorable and manageable habitat for San Francisco lessingia. These satellite reserves help compensate for the irretrievable loss of historic populations and variable dune environments in heavily urbanized parts of San Francisco where no open space remains.

Populations and vegetation within the main San Francisco lessingia recovery units must be restored in settings and locations that will support natural disturbance dynamics that can maintain their long-term integrity without excessive intervention. These sites should also be managed to support associated native dune plant vegetation, including plant species of concern. Potential founder population sources of San Francisco lessingia are limited to a cluster of sites in the Presidio (northwestern range of the species on dune sand) and one remote site in Daly City (southwestern range of the species on sand derived from Pleistocene sand deposits). Seed sources for reintroduction should be selected from the most geographically appropriate remnant populations. Selection of seed sources should consider proximity to modern and historic populations, potential dispersal patterns and edaphic attributes of reintroduction sites (soil texture, mineral, and chemical composition in relation to plant growth). General principles of seed source selection for plant reintroduction are provided by Guerrant (1992, 1996), Falk *et al*. (1996), and Lesica and Allendorf (1999). San Francisco lessingia is an outcrossing annual that was historically widespread in the Presidio dunes. This history suggests that it would be appropriate to establish founder populations from pooled seed collected in multiple modern "populations" in the Presidio. In contrast, founders for new populations at Fort Funston (at the southern end of historic range, nearest the historic collection localities at Lake Merced and Ocean View, and with Colma Formation sand deposits most similar to Merced formation sands) should be obtained only from Daly City. If relevant new data indicate otherwise, recommendations for this seed source selection should be reconsidered. For example, data suggesting high among-population genetic variation within recovery units or substrate specific adaptation may indicate that a different seed source selection strategy is more appropriate. A different strategy may also be indicated if mixed seed source populations have low reproductive output or low viability, as could be caused by inbreeding or outbreeding depression. Restoration and management actions should include reintroduction of extirpated plant species of concern, and at least one potentially-associated endangered species (*Layia carnosa*) at appropriate locations. Additional recovery measures include monitoring, applied research, seed storage, and public education and outreach.

B. Raven's Manzanita (*Arctostaphylos hookeri* G. Don. ssp. *ravenii* P. Wells)

1. Description and Taxonomy

Raven's manzanita is a taxonomically ambiguous shrub within the complex and variable genus *Arctostaphylos* (manzanitas, bearberry). It was most recently classified as *Arctostaphylos hookeri* ssp. *ravenii* (Wells 1968, 1993). Raven's manzanita is a prostrate to ascending evergreen shrub in the heath family (Ericaceae; Figure 8). It was reported to grow less than 60 centimeters (2 feet) tall in historic inland localities (U.S. Fish and Wildlife Service 1984), but the single wild plant today grows nearly prostrate on an exposed coastal site. Raven's manzanita lacks burls (lignotubers), specialized flattened trunk-like structures that are adapted to rapid vegetative regeneration following fires. Its leathery, evergreen, round to round-elliptic leaves are 1 to 2 centimeters (0.3 to 0.7 inch) long, and are isofacial (have the same type of surface on both sides). Flowers are urn-shaped to round, with five-lobed white to pinkish corollas 4 to 5 millimeters (about 0.25 inch) long, with ovaries (floral precursors of fruits containing undeveloped seeds) lacking pubescence (Wells 1993). Flowers appear from mid-winter (in mild winters) to mid-spring (P. Baye unpublished data, U.S. Fish and Wildlife Service 1984). Fruits are tan or brownish, round, and berry-like with thick pulp, containing 2 to 10 stony seeds. The flower stalks are densely covered with fine woolly hairs. Prostrate stems in prolonged contact with the ground are reported to develop roots (U.S. Fish and Wildlife Service 1984). Key distinguishing characteristics of this taxon, based on the single surviving

a b

c

Figure 8. Raven's manzanita (*Arctostaphylos hookeri* ssp. *ravenii).* (a) inflorescence; (b) flowering shoots; (c) site of the remnant clone of Raven's manzanita near the World War II Memorial, Presidio. Adjacent vegetation: Monterey pines (*Pinus radiata*, background); coastal grassland (foreground); and prostrate blue-blossom (*Ceanothus thyrsiflorus*, foreground).

individual plant, are the combination of prostrate juvenile growth habit, round to round-elliptic isofacial leaves, and small flowers and fruits (Wells 1993). California manzanitas have a rich and a complex taxonomic and nomenclatural history (Wells 1991), owing in part to the large number and diversity of species, widespread hybridization, polyploidy (multiplication of chromosome sets), strong geographic variation (especially local intermediates and variants), and local ecological specialization (Markos *et al*. 1999, Raven and Axelrod 1978, Wells 1998). Taxonomic relationships and ranks of *Arctostaphylos* taxa have been variously interpreted and revised throughout the history of California botany (Jepson 1925; Abrams 1951; Munz 1959; Roof 1976, 1978, 1980; Wells 1991, 1998). The taxonomic and nomenclatural history of Raven's manzanita reflects this complexity. Early floras (regional inventories of wild plants) covering San Francisco treated Raven's manzanita variously (and with some confusion) as *Arctostaphylos pumila* Nutt. (Brandegee 1892, Greene 1894), *Arctostaphylos pungens* HBK (Bolander 1863, Behr 1888, Brandegee 1892), or *Arctostaphylos hookeri* (Jepson 1925). More recent floras treated it as Franciscan manzanita, *Arctostaphylos franciscana* (Munz 1959, Thomas 1961) or *Arctostaphylos hookeri* ssp. *ravenii* (Wells 1993), which was disputed by Roof (1976, U.S. Fish and Wildlife Service 1984). Roof (1976) considered it a distinct variety of the variable and wide-ranging Mexican manzanita, *Arctostaphylos pungens* (*Arctostaphylos pungens* HBK var. *ravenii* [Wells] Roof).

Many botanists early in the 20th century treated Raven's and Franciscan manzanitas together as a single variable species. Raven, who rediscovered the Presidio plant that later became the type of his namesake manzanita (Raven 1952, Howell *et al*. 1958) originally treated Raven's manzanita as an ambiguous variant he referred with caution to Franciscan manzanita *(Arctostaphylos franciscana* Eastw.). Franciscan manzanita is a rare endemic San Franciscan manzanita that was entirely extinct in the wild at the time of Raven's discovery, and now exists only in cultivation (see Chapter III, Species of Concern). It was reclassified as *Arctostaphylos hookeri* ssp. *franciscana* in Wells' (1993) treatment of the genus. Raven (1952) also noted that his rediscovered Presidio manzanita was a close match for an Eastwood specimen of Tamalpais manzanita (*Arctostaphylos montana* Eastw. [= *Arctostaphylos hookeri* G. Don. ssp. *montana* (Eastw.) Wells]) from the type locality, Mt. Tamalpais (CAS 38507). Alice Eastwood, an eminent manzanita taxonomist (Wells 1991), also failed to distinguish Raven's manzanita as distinct from Franciscan manzanita, despite familiarity with multiple wild populations (Roof 1980). The past interpretation of Raven's manzanita as a variant of heterogeneous Franciscan manzanita is also reflected in multiple herbarium sheets identified as *Arctostaphylos franciscana* that consist of mixed samples of Franciscan and Raven's manzanitas (e.g., CAS 38903, UC 185733, JEPS 9390, UC 185737, UC 581330; U.S. Fish and Wildlife Service 1984, Roof 1976; T. Daniels, P. Wells, herbarium label annotation in CAS specimens) indicating that early botanists treated them as one entity. These two taxa have different numbers of chromosomal sets (ploidy; n = number of chromosomes in one set = 26 in Raven's manzanita, indicative of doubled chromosome sets, or tetraploidy, n = 13 in Franciscan manzanita, indicative of a single chromosome set, or diploidy; Wells 1968).

In a recent taxonomic treatment of California manzanitas (Wells 1993), Raven's manzanita is distinguished by the character combinations of round leaves, prostrate growth habit that persists in cultivation, small fruits 4 to 5 millimeters (0.15 to 0.19 inch) wide, and nearly spherical flowers 4 to 5 millimeters (0.15 to 0.19 inch) long. By comparison, the sympatric (occurring in the same geographic areas) Franciscan manzanita has oblanceolate leaves (longer than wide, wider toward the tip), larger and reddish fruits 6 to 8 millimeters (0.24 to 0.32 inch) wide, and larger urn-shaped corollas 5 to 7 millimeters (0.2 to 0.28 inch) long (Roof 1980, Wells 1993). Other distinctions between these two taxa are discussed by Roof (1976, 1980; U.S. Fish and Wildlife Service 1984). Tamalpais manzanita (*Arctostaphylos montana*) is distinguished from Raven's manzanita by its elliptic, rarely round leaves (Howell 1949) (typically round-elliptic to round in Raven's manzanita), larger fruits (6 to 8 millimeters [0.24 to 0.32 inch] wide), and more woolly inflorescence axis. Wells (1993) used the prostrate or matted habit of the one remaining Raven's manzanita plant as a general diagnostic trait of the entire taxon. The importance of this trait was disputed by Roof (1976) because of doubts about whether it was inherent species-wide trait, or a circumstantial trait of the one remaining plant on a coastal headland environment. Behr (1892) observed the former (1850's) San Francisco occurrence of the "tall form of Manzanita still growing so abundantly on the slopes of Talmalpais" (presumably a reference to the manzanita later named Tamalpais manzanita [*Arctostaphylos montana*]), located at the site of the Protestant Orphan Asylum near Haight and Laguna Streets. Given the similar appearance of some specimens of Tamalpais manzanita and Raven's manzanita (Raven 1952, Roof 1976), Behr likely observed either former erect types of Raven's or possibly Franciscan manzanita. No specimens of the Orphan Asylum manzanita were collected before the vegetation there was destroyed. Roof (1976) also observed that former mature populations of Raven's manzanita had either ascending or erect growth habits in some sheltered interior San Francisco locations. Roof (U.S. Fish and Wildlife Service 1984) therefore questioned using the prostrate growth habit of the Presidio clone as a diagnostic trait for the species as a whole. Prostrate and ascending growth forms of some low-growing manzanita species, such as the related Tamalpais manzanita, may be attributable in part to environmental factors such as exposure (Howell 1949), maturation (loss of prostrate juvenile growth habit), or to heritable variation in growth habit within the taxon. Historical accounts and herbarium specimens overall suggest that the population of Raven's manzanita formerly exhibited variability in growth habit and vegetative morphology that is now lost. Substantial variability in these traits within California manzanita species is not uncommon (Wells 1993).

Roof (1976, U.S. Fish and Wildlife Service 1984) speculated that Raven's manzanita may have been a derivative of past hybridization between Tamalpais manzanita and bearberry (*Arctostaphylos uva-ursi*) a wide-ranging northern species that today still occurs within the Bay area at Point Reyes and San Bruno Mountain (Howell 1949, Roof 1976, U.S. Fish and Wildlife Service 1984). Tamalpais manzanita occurs almost exclusively on serpentine substrates, but occasionally grows on bare sandstone (Howell 1949, Roof 1976). One particular specimen of Tamalpais manzanita collected from Mt. Tamalpais by Alice Eastwood in 1903 (CAS 35807) was found by Raven (1952) and Roof (U.S. Fish and Wildlife Service 1984) to be very similar to Raven's manzanita, but this form has not been located in recent decades for comparison under modern taxonomic treatment. Other collections of Tamalpais manzanita also have rounded leaves like Raven's manzanita (*L. Rowntree*, CAS 187995*; Abrams 5610*, DS 68655; P. Baye, pers. observ. 1999). Roof considered the round-leaved Eastwood specimen of Tamalpais manzanita to be "scarcely distinguishable from the Masonic Cemetery form" of Raven's manzanita (extirpated, lacking voucher specimens) that he personally observed. Behr (1892) also identified the San Francisco manzanita at the former Orphan Asylum site to be a "tall form" of Tamalpais manzanita; this statement is reasonably interpreted as a reference to the similarity between Tamalpais manzanita and an extinct upright variant of Raven's manzanita.

As interpreted by Wells (Wells 1968, 1993), Hooker's manzanita (*Arctostaphylos hookeri*) consists of a series of five rare subspecies distributed in sandy or rocky coastal environments from Monterey to Marin County. All but subspecies *ravenii* and *franciscana* (= *Arctostaphylos franciscana* Eastw.), which historically occurred together in mixed populations in San Francisco, are geographically isolated from one another. Two taxa, ssp. *hearstiorum* and ssp. *hookeri,* are clustered in coastal Monterey and San Luis Obispo Counties, and are found on sandy soils. Three taxa, (subspecies or species) *ravenii, montana,* and *franciscana,* are clustered around the Golden Gate, and are associated primarily with serpentine bedrock outcrops. The extensive sympatry (co-occurrence in the same geographic area) and lack of ecological differentiation of the two San Francisco endemic manzanitas does not fully fit the concept of the subspecies currently recognized by the International Code of Botanical Nomenclature, which is based on the concept of DuRietz (1930). This subspecies concept is based on a "more or less distinct regional facies of a species," a distinct geographical or ecological race. Nonetheless, the different ploidy levels indicate that these two entities presumably could not freely interbreed as a single population of one species, despite their shared geography, ecology, and structural similarity.

Recent molecular genetic evidence (based on analysis of nucleotide sequences from ribosomal DNA, genetic material from chromosomes of cell's nucleus that code for subcellular structures called ribosomes) suggests that Wells' treatment of *Arctostaphylos hookeri,* including Raven's manzanita,does not comprise a natural group (a unit of classification that reflects shared evolutionary descent)(Markos *et al*. 1999). The genetic analyses of Markos *et al.* (1999) provides evidence that the three manzanita taxa associated with serpentine soils of the Bay area are related by common ancestry(a lineage including Californian *A. uva-ursi* and *A.tomentosa,* or *A. pungens,* depending on the method of analysis). Their analysis indicates that the two endemic San Francisco manzanitas are not closely related to the southern subspecies of *A. hookeri*, which fall in a distinct lineage, despite their overall similarity in some aspects of morphological appearance. Therefore, Wells' subspecies of *A. hookeri* do not all share the same ancestors, making the *A. hookeri* of Wells' classification an "artificial" (paraphyletic) group. The molecular genetic evidence also indicates that the pattern of evolution in these taxa is complex, suggesting either past hybridization or sorting of complex variable ancestors (Markos *et al*. 1999).

The recent molecular genetic analysis of San Francisco manzanita relationships (Markos *et al*. 1999) suggests that it is untenable to retain Raven's manzanita as a subspecies of *Arctostaphylos hookeri* in a natural classification, as Roof (1976, 1980) also earlier suggested on the basis of morphological and ecological evidence. This analysis leaves the taxonomic status and nomenclature of Raven's manzanita once again unresolved and in need of revision. Markos *et al*. (1999) concluded that it would be premature to revise the formal nomenclature and taxonomy of San Franciscan manzanitas until more comprehensive genetic data sets are available for other manzanita taxa. The conventional usage of Wells' nomenclature, popularly used since its publication in the Jepson Manual (Hickman 1993), the standard contemporary revised flora of California, is followed in this recovery plan without prejudice to scientifically valid taxonomic rank or placement of Raven's manzanita.

Raven's manzanita was originally distinguished as a taxonomically distinct entity based on classical morphological methods and chromosome counts (Wells 1968). These methods alone cannot adequately distinguish among "pure" species, hybrids, introgressants, or stabilized hybrid species (reproductive stable populations derived from ancestral hybrid population, unlike sterile or transient unstable hybrids) (Rieseberg 1991), including manzanitas (Ellstrand *et al*. 1987). Indeed, the idea of a "pure" species in *Arctostaphylos*, with its many poorly defined taxa and prevalent hybridization (Wells 1968, 1993; Roof 1976) has often been difficult to apply over the history of taxonomic work in the genus (Wells 1991). Additional research, based on more intensive geographic sampling and molecular genetic analysis, is needed to explore the ancestry of Raven's manzanita and its relationship with the other similar and related manzanitas occurring near the Golden Gate: *A. montana*, *A. franciscana*, and wider-ranging species like *A. uva-ursi*, *A. tomentosa*, and *A. pungens*. Whatever the taxonomic rank and placement of Raven's manzanita, its endangered status and conservation priority remain the same: Holsinger and Gottlieb (1991) argue that stabilized hybrid/introgressant populations are as worthy of conservation as "pure" named taxa.

2. Current and Historic Distribution

Only a single natural clonal colony of Raven's manzanita remains on an ocean-facing serpentine bedrock outcrop within a larger serpentine soil area near the World War II Memorial at the end of Kobbe Avenue in the Presidio, above Baker Beach, San Francisco. All other populations in San Francisco have been extirpated. The clonal colony, rediscovered around 1950, is probably well over a century old (Raven 1952). This population of one plant has been augmented by planting artificially propagated genetically identical daughter clones of the mother plant in its vicinity. Additional genetically identical populations have been established by transplanting clonally propagated (rooted cuttings) plants in the general vicinity of this site at three nearby locations. A clone has also been planted at another serpentine outcrop at Inspiration Point in the Presidio, off Arguello Boulevard. This same clone has also been maintained in cultivated populations in San Francisco and Berkeley. Unlike Franciscan manzanita, no plants of Raven's manzanita were salvaged from former interior San Francisco localities before they were destroyed by urban development. Raven's manzanitas at interior sites may not have attracted conservation attention because they were once considered to be atypical forms of Franciscan manzanita (Roof 1976).

Historic San Francisco manzanita localities that supported both Franciscan manzanita and Raven's manzanita included: (1) the former Laurel Hill Cemetery; (2) the former Masonic Cemetery (near Lone Mountain; the "base of Lone Mountain" locality of "*Arctostaphylos pumila* Nutt." reported by Greene (1894) may have been the Masonic Cemetery locality or a nearby population); (3) Mount Davidson, in the south-central part of the City; and (4) the Presidio locality still surviving (Figure 2). In addition, there is a record of "*Arctostaphylos pumila*" (Behr 1892; a misnomer for either Franciscan or Raven's manzanita, or perhaps both) at the former Protestant Orphan Asylum (Laguna at Haight Street, long urbanized in the late 1800's). Nearly all historic localities of creeping manzanitas in San Francisco were outcrops of serpentine (all sites except Mount Davidson, which comprises greenstone and mixed Franciscan rocks), which suggests limited historic and prehistoric distribution and only local abundance. Evidence for historic mixed populations consists of inadvertent inclusions of Raven's manzanita material within herbarium collections of Franciscan manzanita (see Description and Taxonomy on page 57) and direct observations of co-occurrence (Roof 1976, U.S. Fish and Wildlife Service 1984). Otherwise, definitive historic records and surveys of Raven's manzanita are lacking because it was not recognized as distinct from Franciscan manzanita until long after all but one of its populations were extirpated.

It is possible that the limited historic records under-sampled and under-represented the early historic abundance and distribution of Raven's manzanita. Many collectors of Franciscan manzanita may have consciously or unconsciously selected material most similar to the type of this taxon (Roof 1976), which could have biased the sampling of specimens. Behr (1892) described "*Arctostaphylos pumila*" (not the species endemic to sandy soils near Monterey, but the "creeping manzanita" of Brandegee's San Francisco flora of 1894) as "once abundant" in his botanical memoirs of San Francisco in the 1850's, and predicted its extirpation there nearly a century ago. It is unknown how many populations of San Franciscan manzanitas (mixed Raven's and Franciscan manzanita) occurred during and prior to the 1850's. Herbarium collections of manzanitas in San Francisco were made in the 20th century, after urbanization was well advanced in much of the City.

One other manzanita species, *Arctostaphylos tomentosa* (Pursh) Lindley ssp. *rosei* (Eastw.) P. Wells (= *Arctostaphylos crustacea* Eastw. var. *rosei* [Eastw.] McMinn; shaggy-barked manzanita or rosy manzanita; colloquially, "Brotherhood Way manzanita"), an erect shrub, occurs naturally in southern San Francisco east of Lake Merced on sandy Colma Formation deposits. The nearest populations of other manzanita taxa growing in the wild (including one bearberry, *A. uva-ursi*) are on San Bruno Mountain, San Mateo County (McClintock *et al*. 1990). Bearberry may have occurred in San Francisco during the Pleistocene or earlier in the Holocene epoch (M. Vasey, pers. comm. 1999).

3. Ecology and Reproduction

The available information on the ecology of Raven's manzanita is limited. Direct ecological data include: (1) the records of mixed populations of the endemic San Francisco manzanitas; (2) the restriction of historic localities to bedrock outcrops, primarily of serpentinite; and (3) associated plant species, soil conditions, and microclimate observations at the existing natural locality. Indirect or comparative ecological data include information on similar taxa within *Arctostaphylos*. Generally, available data suggest that Raven's manzanita is a slow-growing, stress-tolerant evergreen shrub that is able to grow on serpentine soils with sparse competing vegetation, but like many manzanitas (Gottlieb 1968, Kruckeberg 1977), is relatively intolerant of competition (especially shading from shrub or tree canopies). It appears to have been locally abundant (Behr 1892) in relatively isolated, localized open serpentinite outcrop colonies, determined by structural geology of the local landscape. Serpentine rocks in San Francisco are restricted to two broad shear zones (bands of rocks deformed and crushed by lateral fault movements): the City College shear zone, and the Hunters Point shear zone (Schlocker 1974, Figure 2).

The degree to which Raven's and Franciscan manzanitas depend on serpentine soil chemistry is questionable. All recorded populations, except the Mount Davidson collections on greenstone, occurred on serpentine substrates, which is circumstantial evidence that they are at least facultative serpentine taxa. However, both Raven's and Franciscan manzanita have been successfully cultivated for many years under nonserpentine, irrigated garden soil conditions without growth abnormalities or indications of nutrient deficiencies (Tilden Park, Berkeley; U.C. Berkeley Botanical Gardens, and Strybing Arboretum; McCarten 1986; D. Mahoney and H. Forbes, pers. comm. 1999). The related and ecologically similar Tamalpais manzanita occurs principally on serpentine, but also thrives on bare sandstone (Roof 1976). The successful growth of Raven's manzanita and related taxa on nonserpentine substrates at multiple locations indicates that they have no specific physiological (nutritional) requirement for serpentine soil chemistry *per se.* This result is consistent with the hypothesis that many instances of serpentine plant endemism (narrow habitat and geographic restriction) are based on the intolerance of competition, and tolerance of harsh serpentine soil conditions that inhibit competition (Kruckeberg 1984), combined with maintenance of sparse, open vegetation. Most other species that occur frequently on serpentine soils in San Francisco (Appendix II) also occur on thin, rocky or clayey soils derived from other types of bedrock.

Soil analysis of the Presidio Raven's manzanita site (McCarten 1986) and other serpentine outcrop sites of the Presidio, confirm that these soils are rich in magnesium, relatively low in major plant nutrients, and are mildly acidic. Soil nitrogen in shallow surface samples (0 to 5 centimeters [less than 2 inches] depth) of Presidio soils, however, were consistently higher than inland Marin County serpentine sites sampled. No data are available on other San Francisco serpentine soils outside the Presidio.

The native plant species associated with Raven's manzanita at the Presidio site have not changed substantially since the 1984 recovery plan (Appendix 3, U.S. Fish and Wildlife Service 1984; Appendix II, this volume) was prepared. Recent additional observations indicate that the wild clone is intermixed with grasses and forbs. The most frequent species interspersed within the manzanita clone include Torrey's melic-grass (*Melica torreyana*), miner's lettuce (*Claytonia perfoliata*), and soap plant (*Chlorogalum pomeridianum*). Species marginally associated with the manzanita clone within low-growing grassland vegetation include red fescue (*Festuca rubra*), junegrass (*Koeleria macrantha*), sedges (*Carex tumulicola*, *Carex* spp.), purple needlegrass (*Nassella pulchra*), California oatgrass (*Danthonia californica*), and goldfields (*Lasthenia californica*) (P. Baye unpublished data 1998). These herbaceous species may have increased in abundance since shrub and tree removal to protect the plant was completed in the 1980's. San Francisco owl's-clover (*Triphysaria floribunda*) and paintbrushes (*Castilleja affinis* ssp. *affinis* and *Castilleja subinclusa* ssp. *franciscana*) have not recently appeared at the site of the remnant Raven's manzanita clone, but were evident in the past (U.S. Fish and Wildlife Service 1984, Howell *et al*. 1958). The endangered Presidio clarkia (*Clarkia franciscana*) population has persisted since its introduction (seeded into the site by J. Roof in 1972; Roof 1972), primarily where steep bedrock outcrops at the surface and minimal soil development is evident. The vegetation within and adjacent to the manzanita colony is either low and herbaceous, or prostrate and woody (blue blossom, *Ceanothus thyrsiflorus*).

Climate and environment affect growth and form of Raven's manzanita. High rainfall appears to promote incidence of twig blight, but also appears to support luxuriant growth later in the growing season (P. Baye unpublished data 1997-1998). Some plants from extirpated populations in sheltered conditions apparently developed a more ascending to erect, but low, growth habit compared with wind-flagged plants on exposed bluffs (U.S. Fish and Wildlife Service 1984; also see discussion in Description and Taxonomy above). Prostrate and erect growth forms of Tamalpais manzanita, controlled by sheltering and exposure, were also noted by Howell (Howell 1949). Mature clones of the Presidio Raven's manzanita genetic individual growing at Tilden Botanical Gardens in warmer, sheltered inland conditions remain strongly prostrate, indicating a strong genetic component to the growth habit of the lone individual from the exposed coastal site (P. Baye, pers. observ. 1998). Prostrate habit may also sometimes be partly a juvenile trait. The marine Mediterranean climate of San Francisco is normally frost-free, with rains largely restricted to fall, winter, and spring months most years (U.S. Fish and Wildlife Service 1984). All historic localities of Raven's manzanita are influenced to varying degrees by persistent marine fogs that depress summer temperatures and reduce intensity of sunlight exposure compared with inland conditions, but there is strong local variation in climate in San Francisco, influenced by topography. Cool fog and onshore winds are typically persistent along the Golden Gate at the type locality of Raven's manzanita, but microclimates at historic localities vary from foggy but relatively wind-sheltered (Masonic and Laurel Hill Cemetery) to intermittently foggy, warmer and sheltered (Orphan Asylum), and intermittently foggy but wind-exposed (Mount Davidson) (P. Baye, pers. observ. 1984-1999).

There are no scientific data on the breeding system of Raven's manzanita, and available evidence is unclear. Raven's manzanita has been reported to be an obligate outcrosser (M. Parker, pers. comm. cited in McCarten 1986), a cross-fertilizing species unable to produce significant amounts of viable seed from self-pollination. Obligate outcrossing plants require at least two genetically compatible individuals to reproduce sexually. The remaining isolated Raven's manzanita in the Presidio, however, has been observed to set seed spontaneously, which suggests either some degree of self-pollination or very long-distance hybrid cross-pollination. Cultivated and wild manzanitas alike readily hybridize among species (McMinn 1939; Wells 1968, 1991; Roof 1976; Ellstrand *et al*. 1987). The wild Raven's manzanita plant, however, is reported to produce few mature fruits and seed (U.S. Fish and Wildlife Service 1984). No mature fruits were observed on the Presidio remnant clone, or its daughter clones, in 1998 or 1999, despite abundant flowering and presence of bees during flowering (P. Baye, pers. observ. 1998-1999). In contrast, both self-pollinated and open-pollinated Raven's manzanita in cultivation at the University of California, Berkeley, have been reported to produce abundant seed, with about 20 percent viability in both lots (40 percent of the fruits with at least one viable seed) in 1995 (H. Forbes, pers. comm. 1999). Tetraploid manzanita species (ones with double sets of chromosomes), such as Raven's manzanita (Wells 1968) generally have significantly lower percentage seed set than diploid species (Kelly and Parker 1991).

There have been no reports of natural seedling establishment around the remnant wild Raven's manzanita or elsewhere since it was rediscovered in 1952. The absence of seedlings may be due to a lack of viable seed, seed predation, or lack of sufficient seedling microsites in the undisturbed vegetation around the single natural plant, or possibly other factors. No data are available on the natural germination ecology of Raven's manzanita. Propagation of other California species of manzanita often requires moist-chilling, scarification (mechanical attrition) of seed coats, or treatments that mimic burns (Lenz 1956, U.S. Fish and Wildlife Service 1984 and references within). It is possible that seed germination of Raven's manzanita would be stimulated by burns (Keeley 1987), as in other manzanita taxa farther south on the San Francisco Peninsula (McClintock *et al*. 1990). Tamalpais manzanita has been observed to regenerate from seed following fire (herbarium sheet annotation, *Eastwood 12980,* CAS 128697). Generally, seed germination of manzanitas is slow and erratic (Lenz 1956), traits consistent with persistent seed banks from which seedlings are recruited following disturbances (Thompson 1992). Naturally occurring dormant seed banks occur in other Californian manzanita species, both in fire-adapted species (post-burn resprouting manzanitas with woody burls rich in regeneration buds) or fire-sensitive species (regenerating only from seed after burns; Kelly and Parker 1990). However, most studies indicate that most seeds produced do not accumulate in soil seed banks, and many seeds are lost to predation (Kelly and Parker 1990).

Nothing is known of the genetic structure of Raven's manzanita prior to its extreme decline to one individual. Roof (U.S. Fish and Wildlife Service 1984) and some herbarium label authors observed layering (rooting of prostrate stems), a form of clonal growth, but natural spread of the clone has so far not resulted in multiple root systems (fragmented clones) of the old wild plant (P. Baye, pers. observ. 1998).

4. Causes of Decline and Threats to Survival

Raven's manzanita was listed as threatened (U.S. Fish and Wildlife Service 1979) based on an analysis of the five factors under section 4(a)(1) of the Endangered Species Act: 1) the present or threatened destruction, modification, or curtailment of its habitat or range (past urban development, vulnerability to management errors due to small population size, competition from other plants); 2) overutilization for commercial, recreational, scientific, or education purposes (possible collection); 3) disease or predation (none noted at time of listing; fungal twig blight occurs in wet years); 4) the inadequacy of existing regulatory mechanisms (limited protection under California law; currently transfer of land to Presidio Trust or private ownership may increase development pressure and reduce protections); and 5) other natural or manmade factors affecting its continued existence (possible lack of pollinators noted at time of listing; also lack of genetic diversity, low reproductive success, and possible hybridization with other manzanitas).

The major cause of historic decline in Raven's manzanita populations was the irreversible elimination of its habitat by San Francisco's urban growth. The lack of seedling colonization in new habitat (possibly due to observed low reproductive output or poor dispersal of seed to isolated patches of suitable seedling habitat)appears to have prevented it from overcoming the adverse effects of local habitat loss and fragmentation. Current threats to its survival are partly due to inherent risks associated with the extreme reduction in population size to a single clone (genetic individual), and partly due to external threats. The external threats to the single Presidio individual that were described in the original recovery plan continue to some extent today, with the exception of shading by trees, which were removed about 1984. The small population of replicate clones on the Presidio is also vulnerable to fire, landslides, accidental injury by road maintenance or vegetation management activities, and vandalism (U.S. Fish and Wildlife Service 1984).

The principal contemporary threat to the persistence of the long-lived original clone of Raven's manzanita is competition (interception of light) by vegetation that overtops the prostrate plant (U.S. Fish and Wildlife Service 1984). The most significant potential competitors are trees that are not native to the San Francisco Peninsula and can overtop and shade the remnant wild manzanita clone: Monterey cypress (*Cupressus macrocarpa*), Monterey pine (*Pinus radiata*), and blue gum trees (*Eucalyptus globulus*). These trees have been removed from the immediate vicinity of the remnant clone (U.S. Fish and Wildlife Service 1984), but reinvasion from abundant local seed sources remains a threat. Other invasive nonnative plants in the vicinity of the manzanita site that represent potential competitive threats include iceplants (*Carpobrotus edulis* and its hybrids), myoporum (*Myoporum laetum*), plume acacia (*Albizia lophantha*), wattles (*Acacia* spp.), jubata grass or "pampas grass" (*Cortaderia jubata*), and nonnative annual grasses. Of these species, jubata grass is now among the most invasive species on serpentine bluffs, scarps, and landslides below the manzanita preserve site. It has proven to be highly invasive to disturbed sites, and produces abundant plumed seed capable of long-distance wind-dispersal. Although jubata grass abundance has recently been suppressed on the bluffs, it recolonizes readily and can grow very rapidly even on serpentine soil (P. Baye, pers. observ. 1993-1999). One native shrub species, a prostrate form of blue-blossom (California-lilac, *Ceanothus thyrsiflorus),* also competes with Raven's manzanita to some extent (U.S. Fish and Wildlife Service 1984), but has apparently co-existed with it for decades without causing progressive decline in the clone.

Ongoing rigorous vegetation management is needed to suppress reinvasion of nonnative vegetation in the immediate vicinity of the preserved clone at the War Memorial site and in the surrounding area, which is a source of nonnative plant seed. Reinvasion will remain a potential threat to the site even if contemporary invasion levels are low. Reducing the effort to suppress these invasive species, even temporarily, would probably enable them to recolonize the preservation site, and resume their threat to the manzanita clone.

In years of frequent and late rains, Raven's manzanita develops relatively extensive infections by a twig blight (called "black smut" in the original recovery plan; U.S. Fish and Wildlife Service 1984) that causes leaf necrosis (tissue death) and dieback of whole sectors of stems in winter and early spring (S. Farrell, pers. comm. 1998). Up to 40 percent of individual clones may suffer dieback in a mosaic pattern during winter months. Affected clones typically quickly recover from blight-induced dieback during the subsequent growing season. Recovery occurs mainly by overgrowth of dead sectors by vegetative shoots from adjacent portions of the clone in spring and early summer (P. Baye unpublished data 1997-1999). Twig blight is likely due to fungus-like disease agents such as *Phomopsis* spp., which affect other species of manzanita as well (Lenz 1956). Cultivated specimens of other native manzanitas at Strybing Arboretum, San Francisco, vary in susceptibility to twig blight in rainy years. At Strybing, the Raven's manzanita clone is relatively susceptible to blight, even compared with Franciscan manzanita. Cultivated clonal replicates of Raven's manzanita in the drier, warmer inland hills of Berkeley (Alameda County) exhibited no blight symptoms after several wet years (P. Baye, pers. observ. 1997-1998). The disease organism responsible for "Sudden Oak Death", a new species of *Phytopthera* (a genus of "water-mold", parasitic algae which include root-rot, stem-rot, and potato-blight diseases) has also been detected recently on at least one native member of the heath family (madrone, *Arbutus menziesii*), and its host range is expanding (Fimrite 2001). This virulent new plant disease has uncertain potential impact on native manzanita species.

The long-term threat of disease to the wild Raven's manzanita clone is uncertain, but the old age of the wild clone suggests that it diseases have been in the past a short-term, cyclic impact, not a progressively degenerative problem. Fungal infection appears to be a greater potential threat to the survival of the smaller daughter clones, which have proportionally more necrotic area when infected. The former variability in pathogen resistance within the entire original population of Raven's manzanita is unknown. Natural genetic variability in pathogen resistance within populations is widespread among plant species (Burdon 1987), and some variation may have been lost with former extirpated populations of Raven's manzanita. Lack of adequate levels of genetic variability in pathogen resistance traits may make plantpopulations more susceptible to disease outbreaks and increased mortality (Burdon 1987, Huenneke 1991). If more virulent strains of twig blight or other pathogens infest the population, dieback could imperil the single wild manzanita clone. Cumulative effects of infection or cumulative increases in inoculum potential (accumulation of diseased leaf litter, a source of spores for reinfection) could also threaten the single clone. Fungicidal treatment of infected plants may be impractical because manzanitas also form obligate associations with beneficial mycorrhizal fungi.

Raven's manzanita's evolutionary potential and its chances for survival in the wild have probably suffered significantly because of its population crash to a single genetic individual (the most extreme genetic "bottleneck" possible). This situation poses a rare challenge for endangered plant species recovery (McMahon 1989, Falk 1992, Knapp and Connors 1999). Modern sexual reproduction of the species appears to be lacking. Since the plant was rediscovered in 1952, no seedling establishment has been detected, although the wild plant does set fruits some years (U.S. Fish and Wildlife Service 1984) with some seed viability (H. Forbes, pers. comm. 1998). The cause of the lack of seedling recruitment is not known, but the challenges of reproduction by seed may be magnified by: (1) the isolation of the plant from open, uncolonized habitat in a heterogeneous, patchy serpentine environment; and (2) deficient adaptive morphological and ecophysiological variation in seedlings produced by a single parent plant. A lack of episodic environmental cues for germination (possibly fire or landslides) around the site of the surviving wild plant may also constrain seedling recruitment.

Recovery of endangered plants faces special problems in small populations (Barrett and Kohn 1991), or populations represented by one (Knapp and Connors 1999) or two (Robichaux *et al*. 1997) genetic individuals. These problems include failure by self-incompatible plants to produce viable seed and inbreeding depression (decreased viability or fecundity [fitness] associated with mating among relatives) (Barrett and Kohn 1991). Populations that typically outcross are expected to be more vulnerable to inbreeding depression than populations with a history of selfing (Barrett and Kohn 1991, Huenneke 1991). Strong inbreeding depression, however, has been observed in some selfing species as well (Barrett and Kohn 1991). Recovery could also be compromised by low levels of genetic variation, especially in traits with adaptive ecological significance. Populations with severely limited genetic variation are most vulnerable to extinction because of reduced potential for evolution in response to environmental changes (Beardsmore 1983, Huenneke 1991, Knapp and Connors 1999). Low levels of genetic variation may also limit evolutionary changes necessary to cope with reintroduction into environmentally variable portions of species' historic ranges (Frankel and Soulé 1981, Huenneke 1991, Lesica and Allendorf 1999), or changes in pathogens or herbivores (Burdon 1987, Huenneke 1991). For exceptionally rare plants like Raven's manzanita, sexual reproduction in populations with adequate levels of genetic variation may be important for continued survival and evolution. Sexual reproduction among genetically diverse individuals recombines (rearranges) genes, possibly creating new combinations of traits that will be subject to natural selection (Crow 1988, Shields 1988).

Assimilation of a rare plant species by hybridization and introgression (repeated backcrossing of a hybrid to one or both parental populations) with nonnative species can also be a threat to survival (Rieseberg 1991, Ellstrand 1992, Levin *et al*. 1996). "Pollen swamping" could occur if nonnative ornamental manzanitas are planted in abundance near the War Memorial manzanita site in the Presidio. The distance from which pollinators are likely to transport manzanita pollen in San Francisco is not known. Production of hybrid seed (with pollen parents of nonnative manzanitas) could permanently corrupt any dormant soil seed banks beneath the Raven's manzanita clone, making natural seedling regeneration unmanageable. This difficulty would also apply to any Raven's manzanita reintroduction sites.

Golden Gate National Recreation Area lands of the Presidio (away from the immediate coastline) were recently transferred to the Presidio Trust, a wholly owned government corporation (16 U.S.C. § 460 bb appendix). This change in management has unclear implications for the recovery of Raven's manzanita. One of the Presidio's mandates is development and leasing of lands in the Presidio for commercial use. In contrast, Golden Gate National Recreation Area had no mandate or authority for commercial development of habitat or park lands. Development of potentially restorable habitat in derelict areas of the Presidio with underlying serpentine rocks could reduce opportunities for restoration, reintroduction, and recovery of Raven's manzanita. Similarly, infrastructure improvements associated with redevelopment (e.g., road widening, slope stabilization, landscaping, recreational amenities, other facilities) could pre-empt habitat restoration in undeveloped serpentine areas. The Trust does not merely need to avoid impacts to existing Raven's manzanita plants; it should provide adequate priority and planning for future endangered species recovery, starting with obtaining complete inventories of outcropping and near-surface serpentine subsoils of the Presidio.

An additional problem for endangered species conservation in the Presidio is that the legislation authorizing the Presidio Trust mandates the transfer of Presidio Trust lands to the Federal government's General Services Administration for disposal (allowing for the possible transfer of land to private ownership) if the Trust fails to meet its financial success criteria after a specified period of time. Disposal of Federal lands to non-Federal jurisdiction would effectively remove much of the legal protection for Raven's manzanita and its habitat (actual or potential) in the Presidio.

Recovery of Raven's manzanita will depend on successful cooperation with owners and managers of potential restoration and reintroduction sites, and their neighbors. Cooperativeness may depend on public and institutional perceptions of the burdens and risks of dealing with federally listed plant species. For example, the environmental assessment for the Golden Gate National Recreation Area's Crissy Field salt marsh and sand dune restoration project (Jones and Stokes 1996) recommended that no endangered species be included in the project, primarily because project managers were concerned that some neighbors expressed discomfort with the idea (N. Hornor, pers. comm. 1996). In San Francisco, publicity over dog leash law enforcement for conservation of western snowy plovers (*Charadrius alexandrinus nivosus*), a federally threatened species, recently raised fears that endangered species would cause unwelcome and burdensome increases in restrictions on recreational uses of urban parklands (D. Hatch, pers. comm. 1994-1998, Miller *et al*. 1997, Golden Gate National Recreation Area 1997). Similarly, removal of planted nonnative trees in San Francisco for purposes of habitat restoration may engender strong opposition even before restoration goals and methods are articulated(J. Sigg and P. Holloran, pers.

comm. 1998). Public outreach and education will be necessary to ensure that unrealistic perceptions of regulatory burdens, recreational public land use, and esthetic changes associated with habitat restoration and reintroduction do not impede recovery actions for Raven's manzanita. Schools, horticultural and conservation organizations, and community organizations should be involved in public outreach to prepare for implementation of recovery actions. Pilot projects involving small-scale reintroduction of Raven's manzanita, or authorized local public horticultural displays (Reinartz 1995), should precede more ambitious recovery actions to demonstrate and promote compatibility with urban land uses, and to establish public confidence and cooperation.

5. Conservation Efforts

We proposed Raven's manzanita for Federal listing as endangered on June 16, 1976. The species was listed as endangered on October 26, 1979 (U.S. Fish and Wildlife Service 1979). It was also listed as endangered by the State of California in 1978 (California Department of Fish and Game 1992). We published a final recovery plan for the species on July 10, 1984, prepared by manzanita experts Jim Roof and Alice Howard. The recovery priority number for Raven's manzanita is 12, indicating a subspecies with a moderate degree of threat and low recovery potential (see criteria published by *Federal Register* Notice (48 FR 43098; September 21, 1983).

Since the publication of the 1984 recovery plan, the Golden Gate National Recreation Area and its volunteers significantly reduced competition by nonnative vegetation around the natural Raven's manzanita clone, removing Monterey cypress, iceplant, and nonnative grasses, and minimizing recolonization by these species. Symbolic fencing, interpretive signs, and improved coordination with road maintenance and other staff of the Golden Gate National Recreation Area have reduced threats of trampling and accidental damage. These actions have resulted in expansion of the clone in a generally healthy condition most years.

In January 1987, the Presidio (then managed by the U.S. Army) and the Golden Gate National Recreation Area cooperatively propagated 168 cuttings of the wild clone, from which 50 propagated plants survived to be planted in the Presidio. In

December 1987, the Golden Gate National Recreation Area established one small colony of daughter clones around the parent clone, two small colonies in the vicinity of the original plant, and one transplant about a mile away from it (U.S. Fish and Wildlife Service recovery file information). This work is a step toward, but far short of, the 1984 recovery plan's prescription for 5 populations of at least 20 plants each. The Golden Gate National Recreation Area has prepared a comprehensive vegetation management plan for the Presidio (Golden Gate National Recreation Area and Presidio Trust 2000), which is expected to propose increased protection and maintenance of the habitat of the mother and daughter clones at the World War II Memorial site and transplants introduced to other Presidio locations. Tilden Park (East Bay Regional Parks) and the University of California, Berkeley, have maintained their collections of both endemic San Francisco manzanita taxa. Strybing Arboretum has maintained a single replicate clone of Raven's manzanita, but it has declined precariously in recent years due to blight and high rainfall. The University of California, Berkeley, obtained open-pollinated and self-pollinated seed from approximately 4,500 fruits harvested from cultivated clones in 1995 (H. Forbes, pers. comm. 1999), from which 12 seedlings from the open-pollinated source were obtained under experimental germination conditions; it is unclear whether these seedlings are pure strains (selfed), hybrids, or mixed.

6. Species Recovery Strategy for Raven's Manzanita

The recovery of Raven's manzanita has three basic objectives, one of which has been added to those prescribed in the original recovery plan (U.S. Fish and Wildlife Service 1984). The first basic objective is to continue to protect the existing remnant natural clone against foreseeable threats and ensure its natural survival. This objective has been achieved, but requires ongoing effort. The second objective is to reduce the chance of Raven's manzanita's extinction by increasing the number of independent populations of the original clone at various locations in the Presidio, spreading the risk of mortality among many replicate colonies. These two objectives, continued from the original recovery plan, are focused only on avoiding extinction of the species under highly managed conditions, not on its continued evolution and conservation of the ecosystem on which it depends (Endangered Species Act section 2(b), PL 100-478). Recovery efforts under the original recovery plan were based primarily on protection of the remnant clone, or on artificial propagation and transplanting of replicate clones; there was limited emphasis on developing spontaneous reproduction of variable plants in “self-sustaining” populations or habitat. This revised recovery plan now includes objectives to restore sexual reproduction and regeneration of Raven’s manzanita, and restore its potential natural ecological interactions with native associated species, including potential rare gene flow between it and the related Franciscan manzanita.

To make these multiple objectives compatible, the original remnant clone and its associated native vegetation should be treated conservatively (protecting the local plant assemblage in which it occurs, managing it by removing nonnative species). For the foreseeable future, additional Presidio populations should be clones of the original, unless new “pure” clones (seedlings resulting from self-fertilization of the original clone) are obtained. The Presidio should be a refuge for “pure” Raven’s manzanita, either clones of the original or inbred seedlings, which requires protection of existing suitable habitat, or the establishment of new habitat. When Raven’s manzanita is reintroduced to existing suitable habitat, it is important that new transplanted populations do not harm rare established native serpentine vegetation. The most abundant opportunities for reintroduction occur below Lincoln Boulevard on the serpentine bluffs (stable and unstable landslides), where relatively bare serpentine soil slopes and serpentine bedrock outcrops are still found. Exposed serpentine rocks and soils also occur behind Crissy Field, near Fort Point, Inspiration Point, and a few other locations (McCarten 1986). Unexposed near-surface serpentine rocks and soils are also likely to occur along the shear zone (Figure 3) elsewhere in the Presidio.

Multiple experimental populations of sexually reproductive Raven’s manzanita should be established at interior San Francisco locations isolated from the Presidio, preferably on serpentine outcrops near or similar to those of historic (extirpated) localities. Because of the strong geographic and ecological isolation between the Presidio and interior San Francisco localities, a wider range of experimental reintroduction methods may be attempted with minimal risk to the species. The establishment of new populations should be combined with restoration of associated local serpentine plant species assemblages. Restoration of appropriate plant assemblages would have to include reintroduction of Franciscan manzanita in mixed populations. The relatively small size of such urban reserves would be compatible with the historic natural distribution of serpentine outcrop vegetation in San Francisco, which was a pattern of small, discontinuous, localized sites.

No specific historic localities of former populations of Raven's manzanita outside the Presidio contain potentially restorable habitat. However, potentially restorable serpentinite-bearing sites occur at geologically related parts of the Fort Point-Potrero Hill-Hunters Point shear zone (Figure 3). Potentially restorable sites also occur within the same serpentinite-bearing formations elsewhere in San Francisco along the City College shear zone (such as Lands End; Figure 3). Parks, undeveloped steep slopes, and road cuts in serpentine rocks represent opportunities for both small-scale and large-scale reintroduction experiments. Examples of potential small urban reserves may be found near Potrero Hill (e.g., Starr King Park). Secure Federal lands with large serpentine outcrops occur around the U.S. Mint at Duboce Street. Undeveloped land at the historic Mt. Davidson locality, on greenstone, has potential for habitat restoration and reintroduction. Other greenstone outcrops in undeveloped steep slopes occur locally around Twin Peaks and Sunset Heights, and elsewhere (Figure 2; map in Schlocker 1974). Other Franciscan rock outcrops with vegetation similar to that of serpentine rocks could also be the subject of reintroduction experiments. Establishment of viable populations of Raven's manzanita at these locations could potentially provide habitat and populations that are roughly equivalent to those that were extirpated.

Planning for experiments to reintroduce Raven's manzanita into interior San Francisco should begin by surveying contemporary conditions of mapped bedrock outcrops of serpentine rocks and greenstone. Exposures should be assessed for conservation potential (size, access, adjacent land use compatibility, maintenance potential, vegetation restoration potential) and potential for management and protection (public/private ownership, landowner interest, costs for easements or fee title acquisition, compatibility with recreational or other land use, community support) with serpentine being the higher priority. The San Francisco Department of Parks and Recreation owns and manages many semi-wild vegetation remnants in San Francisco, often in cooperation with local community groups, conservation organizations, and schools.

The potential for sexual reproduction of offspring with adequate variability in ecologically adaptive traits in Raven's manzanita should be assessed. The highest initial priority would be to generate new seedling-grown plants resulting from self-fertilization (inbreeding) under controlled conditions. Viable seeds from several hundred fruits were collected from cultivated plants at the University of California, Berkeley. These seeds were reportedly produced by self-pollination alone (H. Forbes, pers. comm. 1999). Currently, the University of California, Berkeley Botanical Garden has 12 juvenile offspring derived from uncontrolled open pollination of cultivated clones of Raven's manzanita (H. Forbes, pers. comm. 1999). These plants have not yet been cloned or tested for possible hybridity. Additional attempts should be made to breed new "pure" genetic individuals ("selfed" or inbred seedlings). The pedigrees of any plants resulting from inbreeding plants would need to be recorded, and plants would need to be genotyped (genetic individuals distinguished by heritable "marker" traits or genes) and evaluated for indications of inbreeding depression (loss of fitness, i.e. decreased viability or reproductive output, due to inbreeding). If the inbreeding program yields significant numbers of viable plants, they should be propagated clonally, and pedigreed clones should be reserved in cultivation, then reintroduced to the wild or restored habitat.

Inbreeding may fail to generate viable cultivated stock of "pure" Raven's manzanita. Since the only seedlings successfully grown from Raven's manzanita fruits were from open-pollinated plants (no seedlings were obtained from viable seed of selfed plants at the University of California, Berkeley; H. Forbes, pers. comm. 1999), and no seedlings of Raven's manzanita have ever been observed in the wild, it is quite possible that this plant is an obligate outbreeder. Even if viable inbred plants are produced, it is possible that the Presidio clone from the windswept coastal bluff site may yield a limited range of genetic individuals that would not be well adapted to the novel soil, vegetation, and microclimates of interior San Francisco reintroduction sites. To restore levels of fertility and genetic diversity to obligate outcrossing plant taxa that have been reduced to single genetic individuals (e.g., *Castilleja uliginosa, Physostegia correllii,* *Hedyotis parvula, Betula murrayana, Pritchardia munroi, Prunus maritima* var. *gravesii*; McMahan 1989), one possible strategy is a breeding program based on introgressive hybridization with closely related species, or genetically distinct populations (Knapp and Connors 1999). Peter Raven and the late Robert Ornduff had suggested applying this strategy to the sole survivor of the obligate outcrossing species, *Castilleja uliginosa* (Falk 1992). Introgressive breeding is part of the recovery plan for *Kokia cookei*, a Hawaiian plant that persists only as a single genetic individual, in cultivation (U.S. Fish and Wildlife Service 1998*d*). Introgressive breeding is an extraordinary strategy for recovery of an extremely rare plant, but ordinary concerns about the integrity of genetic diversity within species may be effectively irrelevant when a species is reduced to a single individual (Falk 1992). When the single survivor represents an obligate outcrossing species that would be extremely unlikely to reproduce spontaneously, extraordinary genetic management approaches may be appropriate (Falk 1992).

Introgressive breeding is a strategy of last resort to recover near-extinct species (Rieseberg 1991). It is based on developing first-generation (F_1) hybrids between the rare species (or distinct population) and a closely related species or population, and crossing these F_1 hybrids both back among themselves, and on the rare parent species or population. Segregants of F_2 hybrids (second generation hybrids, individuals with various combinations of parental traits) would be selected for those that are essentially indistinguishable from the rare parent. This strategy would result in generations of individuals with genetic backgrounds derived mostly from the rare species (depending on the number of backcrossed generations), but with increased genetic diversity. This combination of backcrossing and selection is a breeding strategy that is long established in cultivated plants for horticultural and agricultural purposes (Briggs and Knowles 1965). For slow-growing woody species like manzanitas, this breeding program would take many years or decades because of the time needed for each seedling generation to reach sexual maturity.

If attempts to generate genetically variable, viable, and fertile robust inbred lines from the single Raven's manzanita (the first priority) are unsuccessful, the introgressive hybridization approach should be attempted as an alternative to perpetual artificialpropagation and planting to achieve survival of a single asexual clone and as a last chance for continued evolution of the species. Evaluation of the need and appropriateness for a breeding program for Raven's manzanita should be conducted by an expert scientific peer review panel. A genetic management plan describing the breeding program and how any progeny would be used in reintroduction should be developed collaboratively by the U.S. Fish and Wildlife Service, National Park Service (Golden Gate National Recreation Area), and the scientific panel. The panel should include experts in manzanita biology, plant conservation genetics, plant breeding, and plant propagation.

A leading candidate taxon for an experimental introgressive breeding program with Raven's manzanita is Tamalpais manzanita (*Arctostaphylos montana* [= *Arctostaphylos hookeri* ssp. *montana*]). It is geographically, ecologically, morphologically, and taxonomically close to Raven's manzanita (see Description and Taxonomy). Recent genetic analysis (Markos *et al.* 1999) confirmed that this species is related to its rare serpentine counterparts south of the Golden Gate, and it shares the same number of chromosomes as Raven's manzanita (Wells 1993). Wells (1993) treated both taxa as subspecies of the same species, and they are distinguished by few morphological traits, some of which may be artifacts of lost variability in Raven's manzanita (Behr 1892, Roof 1976). Research is needed to further clarify which manzanita taxa or populations would be most suitable for inclusion in a breeding program with Raven's manzanita, how compatible genetically they are, and how the plants resulting from introgressive progeny compare with Raven's manzanita in ecological and morphological characteristics.

Introgressive breeding of Raven's manzanita introduces risks that intercross individuals may mistakenly be planted as "pure" Raven's manzanita (label error, propagation errors). Such errors could potentially result in gene flow to the "pristine" Presidio population or confusion between "pure" clones and intercross individuals. If introgressive plants are bred, they should be restricted to isolated interior San Francisco locations, and separated from the Presidio. However, the concept of "pure" manzanita species is sometimes considered artificial (see Description and Taxonomy) given the strong indications of widespread natural hybridization in the evolution of the genus (Gottlieb 1968, Keeley 1976, Ellstrand *et al.* 1987, Wells 1991, Schierenbeck *et al*. 1992).

Because of the vulnerability of the single existing plant of Raven’s manzanita, conservation in botanical gardens will continue to play a role as a hedge against extinction in the wild. Cultivation, however, is not an alternative to recovery in wild populations. Cultivation provides benefits for scientific and educational objectives, and for public outreach, but cannot achieve the Endangered Species Act’s basic purpose of conserving endangered species in their natural ecosystems. Cultivated populations are essentially static and lack dynamic ecological and evolutionary processes.

III. OTHER FEDERALLY LISTED SPECIES AND SPECIES OF CONCERN OR REGIONAL CONSERVATION SIGNIFICANCE

The principal causes of decline and endangerment of San Francisco lessingia and Raven's manzanita have been loss of populations and habitat caused by urbanization of San Francisco, and degradation of remnant habitat quality. The habitat destruction associated with San Francisco's urban growth has significantly impoverished the flora of the San Francisco Peninsula, and also contributed significantly to the decline of other federally listed species that are native there. These species include California sea-blite (*Suaeda californica*; U.S. Fish and Wildlife Service 1994), marsh sandwort (*Arenaria paludicola*; Behr 1892, U.S. Fish and Wildlife Service 1998*b*), beach layia (*Layia carnosa*; U.S. Fish and Wildlife Service 1998*b*), Marin dwarf-flax (*Hesperolinon congestum*; U.S. Fish and Wildlife Service 1998*a*), and Presidio clarkia (*Clarkia franciscana*; U.S. Fish and Wildlife Service 1998*a*).

Urbanization has also caused or contributed to the decline of a host of other plant species, including some that are now extirpated over parts of their range, nearly or entirely extinct in the wild, or declining toward rarity and endangerment. These species of concern are not currently federally listed as threatened or endangered, but many could become so in the future. Some may be proposed for listing once adequate survey information is available. Other species of local or regional conservation significance include those that remain relatively secure in populations elsewhere, but have undergone substantial range reduction, and have become rare or locally extirpated on the San Francisco Peninsula.

The fundamental aim of this recovery plan is to address the conservation needs of its endangered species within their ecosystems, including their associated species of concern, and other species of regional conservation significance. Recovery actions aimed at protection, management, and restoration of habitat and populations of listed species should incorporate appropriate conservation actions for these associated species.

Site-specific actions undertaken pursuant to this recovery plan may include reintroduction, removal or eradication of nonnative invasive vegetation to indirectly benefit the native plants, or temporary protective measures to avoid adverse impacts to existing populations in the course of habitat restoration. Such actions must be consistent with any existing recovery plans covering listed species on the Presidio.

A. Ecologically Associated Federal Listed Species

Several other federally listed species occur within the geographic and ecological scope of this plan: Presidio clarkia (*Clarkia franciscana*), Marin dwarf-flax (*Hesperolinon congestum*), and beach layia (*Layia carnosa*). Serpentine and sand dune habitats of San Francisco are also within the historic range of the bay checkerspot butterfly (*Euphydryas editha bayensis*) and Myrtle's silverspot butterfly (*Speyeria zerene myrtleae*). These species are covered comprehensively throughout their full geographic ranges in two other recovery plans: the Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (covering bay checkerspot butterfly, Presidio clarkia, and Marin dwarf-flax; U.S. Fish and Wildlife Service 1998*a*) and the Recovery Plan for Seven Coastal Plants and the Myrtle's Silverspot Butterfly (covering Myrtle's silverspot butterfly and beach layia; U.S. Fish and Wildlife Service 1998*b*). The reader is referred to these documents for more extensive treatment of the recovery needs of these species. Below are summary accounts of these species. Tasks and recommendations from all relevant recovery plans should be incorporated in areas where these species are ecologically associated with the species covered in this recovery plan. For example, Presidio clarkia was seeded into the serpentine habitat of Raven's manzanita nearly three decades ago (Roof 1972), even before its Federal listing, and has persisted since then.

1. Presidio Clarkia, *Clarkia franciscana* Harlan Lewis & Raven

Presidio clarkia (*Clarkia franciscana*) is a slender, erect annual herb in the evening-primrose family (Onagraceae) (Figure 9). The ecology and recovery of this species are covered comprehensively in the Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (U.S. Fish and Wildlife Service 1998*a*). It has showy pink and purple flowers in spring and early summer on grasslands of serpentine soils and outcrops. Presidio clarkia is similar to *Clarkia rubicunda*, which occurs in open grassland and scrub vegetation on the San Francisco Peninsula (McClintock *et al*. 1990), but *Clarkia rubicunda* is not a close ancestor of Presidio clarkia, as had

PINK SAND-VERBENA
Abronia umbellata ssp. *umbellata*

FRANCISCAN MANZANITA
Arctostaphylos franciscana
(=*A. hookeri* ssp. *franciscana*)

NUTTALL'S MILK-VETCH
Astragalus nuttallii var. *virgatus*

INDIAN PAINTBRUSH
Castilleja affinis ssp. *affinis*

Figure 9. Selected plant species from the northern San Francisco Peninsula that are ecologically associated with either serpentine or dune vegetation. Species are ordered alphabetically by their botanical name.

SEASHORE STARWORT
Stellaria littoralis

DUNE TANSY
Tanacetum camphoratum

Figure 9 (continued). Selected plant species from the northern San Francisco Peninsula.

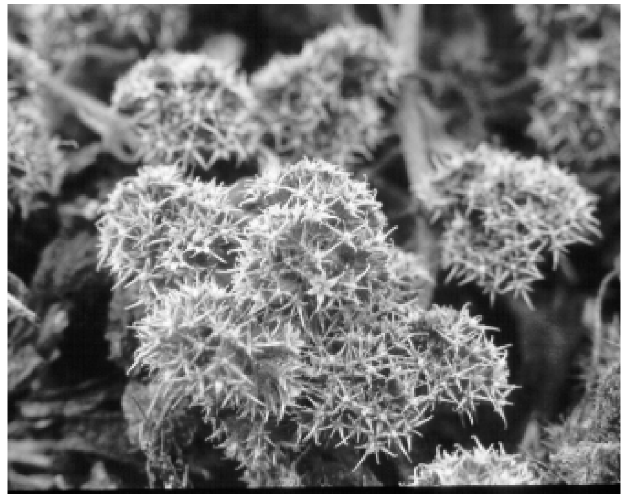
CURLY-LEAVED
MONARDELLA
Monardella undulata

BEACH LAYIA
Layia carnosa
(Federally endangered)

COMMON LINANTHUS
Linanthus parviflorus

COAST PIPERIA
Piperia elegans

Figure 9 (continued). Selected plant species from the northern San Francisco Peninsula.



BANDED PURPLE OWL'S-CLOVER
Castilleja exserta ssp.*latifolia*

SAN FRANCISCO SPINEFLOWER
Chorizanthe cuspidata

FRANCISCAN THISTLE
Cirsium andrewsii

PRESIDIO CLARKIA
Clarkia franciscana
(Federally endangered)

Figure 9 (continued). Selected plant species from the northern San Francisco Peninsula.

SAN FRANCISCO DUNE GILIA
Gilia capitata ssp. *chamissonis*

FRANCISCAN WALLFLOWER
Erysimum franciscanum

SAN FRANCISCO GUMPLANT
Grindelia hirsutula ssp. *maritima*

MARIN DWARF-FLAX
Hesperolinon congestum
(Federally threatened)

Figure 9 (continued). Selected plant species from the northern San Francisco Peninsula.

previously been concluded (Gottlieb 1973). Presidio clarkia is a predominantly self-pollinating plant (Lewis and Raven 1958). Population sizes fluctuate strongly among years. In some years populations drop to zero (Roof 1971), and apparently regenerate from seedbanks in more favorable years like other native annuals. Experience with vegetation management in the Presidio suggests that Presidio clarkia's reproductive success may depend on the competing vegetation being sparse. The remnant wild Presidio population was established on a former serpentine rock quarry (Roof 1971). Population declines appear to be associated with encroachment by nonnative vegetation, particularly dense growth of annual nonnative grasses (M. Albert and S. Farrell, pers. comm. 1998).

Presidio clarkia is known from only two natural populations: one in San Francisco (Inspiration Point, Presidio) and a series of subpopulations in the Oakland Hills (Gottlieb and Edwards 1992). An artificially seeded population in the Presidio (World War II Memorial, adjacent to the parent clone of Raven's manzanita) occurs on a coastal serpentine outcrop above the north end of Baker Beach. It was established there by translocation of seed in 1972 (Roof 1972), and has persisted since then at population sizes ranging from tens to hundreds of plants. In 1994, 860 plants established at this introduced population, while 8,716 grew at the managed natural Inspiration Point population (Golden Gate National Recreation Area unpublished data 1994). The main population on the Presidio is protected against development, but it remains strongly threatened by introduced conifers and eucalyptus trees, weedy herbaceous nonnative plant species, trampling, and unfavorable mowing times (prior to seed maturation and dispersal). Potential development of Presidio Trust lands currently unoccupied by Presidio clarkia, but containing serpentine outcrops and soils, may preempt habitat restoration that may be needed for recovery of this species. Because some recovery actions for Raven's manzanita in serpentine habitat within the Presidio may benefit Presidio clarkia within manzanita habitat (as demonstrated by the successful establishment of the World War II Memorial population of Presidio clarkia) recovery actions for Presidio clarkia should be integrated with those of Raven's manzanita. Recovery actions for Raven's manzanita that may benefit Presidio clarkia include enhancement of serpentine habitat quality (e.g., removal and suppression of invasive nonnative grasses, iceplant, and conifers). Resources for recovery of both endangered species could be allocated efficiently by reintroducing both to unoccupied suitable serpentine outcrop habitat on the Presidio bluffs.

2. Marin Dwarf-flax, *Hesperolinon congestum* (Gray) Small

Marin dwarf-flax (*Hesperolinon congestum*) is a small (usually less than 15 centimeters [6 inches]) annual herb in the flax family (Linaceae) (Figure 9). This federally threatened species is addressed in the Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (U.S. Fish and Wildlife Service 1998*a*). It has threadlike stems and linear leaves. Its flowers, which have five rose-to-whitish petals and deep pink or purple anthers, are borne in clusters. Marin dwarf-flax is known from fewer than 20 serpentine soil localities in Marin, San Francisco, and San Mateo Counties. It is closely related to the more widespread California dwarf-flax (*Hesperolinon californicum*), from which it is distinguished by its hairy sepals, dark pink/purple anthers, and exclusive serpentine habitat. It occurs in serpentine grassland soil outcrops above Baker Beach, near the one remaining natural Raven's manzanita location. California dwarf-flax, but not Marin dwarf-flax, co-occurs with Raven's manzanita at the World War II Memorial site. Marin dwarf-flax was historically reported from the former Laurel Hill Cemetery (now urbanized) and Lone Mountain (urbanized) around the turn of the 20th century (Howell *et al*. 1958). Its decline in San Francisco is attributable to urban development, invasion by dominant nonnative vegetation, and trampling.

3. Beach Layia, *Layia carnosa* (Nuttall) Torrey and Gray

Beach layia (*Layia carnosa*) is a prostrate to low erect annual fleshy-leaved herb in the aster family (Asteraceae) (Figure 9). The biology and ecology of this plant are summarized in the Recovery Plan for Seven Coastal Plants and Myrtle's Silverspot Butterfly (U.S. Fish and Wildlife Service 1998*a*). Beach layia germinates during winter rains and grows as a vegetative rosette until spring, when flowering shoots bolt. Individual plants produce from 1 to over 100 seed heads. Seeds (achenes) have a bristly pappus that facilitates wind dispersal. The species is locally common, but occurs in few populations that are widely scattered from Humboldt County to Santa Barbara. It occurs only in sparsely vegetated coastal dunes in the Humboldt Bay area, Point Reyes, Monterey Peninsula, and Vandenberg Air Force Base. The largest populations occur in dunes around Humboldt Bay and Point Reyes.

Beach layia was reported from San Francisco (Thomas 1961), although no herbarium specimens from San Francisco are found in the herbaria of the California Academy of Sciences, Dudley/Stanford (P. Baye, pers. observ. 1997), Jepson, or University of California (CALFLORA 1999). Unless it was misreported, it probably consisted of small local populations in San Francisco, since it was not detected by the preparers of San Francisco floras prior to 1961 (Brandegee 1892, Howell *et al.* 1958). It is currently absent in San Francisco, where suitable habitat for reintroduction exists (e.g., portions of Ocean Beach, Golden Gate National Recreation Area; Crissy Field dune restoration area; and Fort Funston dunes), and can be expanded. Reintroduction and habitat expansion would be consistent with the approved recovery plan for this species.

Beach layia occurs in a wide range of successional phases of coastal foredunes, dune grassland, and scrub, but is always associated with sparse, open sandy areas. At Point Reyes, the nearest population to San Francisco, it occurs in semi-stable foredunes, sparsely vegetated blowouts in dune scrub, and active bare dunes. It grows in Point Reyes dunes in both relatively recently deposited dune sand as well as in openings in older dunes with relatively weathered, organically enriched old sandy soil (comparable to modern localities of San Francisco lessingia) (P. Baye, pers. observ. 1985-1999).

Reproductive output of beach layia corresponds with plant size, and both are relatively greater in microenvironments with elevated soil moisture (edges of dune slacks and lagoons) or organic matter (older dune soils). Population size of this annual species fluctuates strongly from year to year. It is endangered by loss of habitat and degradation of its habitat due to extensive establishment of European beachgrass (*Ammophila arenaria*), as well as iceplant and other invasive nonnative vegetation (U.S. Fish and Wildlife Service 1998*b*).

4. Myrtle's Silverspot Butterfly, *Speyeria zerene myrtleae*

Myrtle's silverspot butterfly (*Speyeria zerene myrtleae)*, an endangered member of the brush-footed butterfly family (Nymphalidae), historically ranged from coastal San Mateo County (Pescadero) to northern Sonoma County. It inhabits coastal dunes, coastal scrub, and coastal grasslands that support adequate nectar sources and the larval host plant, western dog violet (*Viola adunca*) (U.S. Fish and Wildlife Service 1998*b*). The host plant occurred historically in grassland at localities of both historic and remnant dunes in San Francisco (Baker Beach, Sunset Heights; Howell *et al*. 1958). Though now rare or locally extirpated at these and other localities of existing and proposed San Francisco lessingia populations, dog violet and possibly Myrtle's silverspot butterfly could potentially recolonize or be reintroduced to San Francisco lessingia recovery units. Such reestablishment would be consistent with the approved recovery plan for this species.

5. Bay Checkerspot Butterfly, *Euphydryas editha bayensis*

The threatened bay checkerspot butterfly is associated with serpentine grassland habitats, but it also occurred historically at Twin Peaks in San Francisco (not a serpentine area, but bearing other Franciscan bedrock outcrops) and San Bruno Mountain (U.S. Fish and Wildlife Service 1998*b*). Its primary larval food plant is dwarf plantain (*Plantago erecta*; U.S. Fish and Wildlife Service 1998*b*). Dwarf plantain is still locally abundant in San Francisco and San Mateo County, occurring on remnant and restored older sand dunes with some soil development, and on thin soils of Franciscan bedrock outcrops composed of greenstone, serpentine, or sandy Pleistocene sediments (P. Baye, pers. observ. 1996-1999). Secondary, alternative larval host plants include purple owl's-clover (*Castilleja exserta* = *Orthocarpus purpurascens*), a species of local conservation significance (see section C below) that is extirpated in San Francisco (P. Baye, pers. observ. 1984-1999), but persists nearby on coastal grasslands at headlands in Pacifica, San Mateo County (Rockaway Head; P. Baye, pers. observ. 1999) and locally in older Point Reyes dunes (P. Baye, pers. observ. 1999). Purple owl's-clover was formerly locally abundant in dunes and coastal grasslands of San Francisco (Howell *et al*. 1958).

Restoration of coastal dune grassland and Franciscan bedrock outcrops (particularly where they occur together in large potential reserve areas - e.g., Sunset Heights, Baker Beach), with reintroduction of the host plant species, would provide opportunities for reintroduction or spontaneous recolonization of a bay checkerspot butterfly population. Such reestablishment would be consistent with the approved recovery plan for this species.

B. Species of Concern

The following species occurred in the historic flora of San Francisco and northern San Mateo County as components of dune or bedrock outcrop vegetation, and are either known or probable associates of Raven's manzanita or San Francisco lessingia. They are now either in major local decline, locally rare, locally extirpated, or locally extinct in the wild (surviving only in cultivation). Some of these rare species have few or no recent records or survey information, and may warrant future listing as threatened or endangered species. The plant assemblages in which they were included were part of the ecological and evolutionary background of the two endangered species featured in this plan. Recovery of the ecosystem in which these listed species occur should include restoration of the approximate vegetation and flora it supported.

Little is known about the interactions between San Francisco lessingia or Raven's manzanita and their native plant associates. Some interactions may be antagonistic, such as shading by taller shrubs or nutrient or water competition below ground. But interactions between plants may be positive at some life-history stages, such as partial foliar shading, which reduces moisture stress of seedlings, or persistent leaf litter, which traps seeds in favorable microsites. Some native competitors may help exclude establishment of nonnative invasive species that are more antagonistic to listed species. Other potential interactions include attraction of insect pollinators, modification of soil nitrogen content (nitrogen fixation), extraction of nutrients from different strata of the soil profile, and sheltering or "nurse plant" effects on seedlings. The relative frequency of contacts among less common species is also unknown or poorly known; some may have directly associated with one another, and some may have occupied distinctly different microenvironmental patches within the same vegetation. It is impractical (or impossible) to perform an adequate comprehensive study of plant interactions in local dune and rock outcrop vegetation. Thus, it is prudent to reassemble the historic elements of the vegetation to the extent possible, based on historic records and assessment of representative stands of similar vegetation in the region, and allow community dynamics to reconstitute themselves to some degree. The reconstitution of serpentine and dune plant communities dominated by the native species that were historically present is essential to full recovery of Raven's manzanita and San Francisco lessingia.

The most basic tenet of restoration of plant communities is not to lose the parts that compose them. Some of the plant species of concern have apparently been lost in the San Francisco flora, at least outside of cultivation. Some species persist in San Francisco, but have been extirpated in distinct types of plant communities, such as dune scrub and grassland, where local, ecologically distinctive populations are likely to evolve. It is also possible that some apparently extirpated species are "latently" present as dormant seeds in the soil, awaiting regeneration following disturbances to soil and vegetation (Thompson 1992). Conservation of these species should rely first on protecting and, where feasible, expanding existing remnant populations, particularly in dune and rock outcrop habitats. The first priority for conservation of species of concern should be to expand local populations rather than import propagules from offsite, to retain the character of local populations. Populations can sometimes be expanded by enhancing habitat quality and allowing natural spread, which is a preferable method. In remnant natural areas of San Francisco, population expansion is often made possible by removal of nonnative plants, thwarting their re-invasion, and managing disturbances such as excessive trampling. Where conditions for establishment are more difficult, artificial propagation of local stock or seed and outplanting (population augmentation rather than reintroduction) may be appropriate.

For species known or presumed to be extirpated, systematic surveys should be conducted in suitable habitat at appropriate seasons for detection. For species that are locally extirpated, reintroduction from appropriate source populations should be attempted experimentally. Reintroductions of these species of concern to places where they have been extirpated should be presumed to be difficult and will have to be conducted on an experimental basis because of the many uncontrolled variables affecting restored habitats (rainfall and drought, pathogens, herbivory, nonnative competitors). Like natural dispersal and establishment of founder populations (Primack 1996), reintroductions often have low probabilities of success, and may require much repetition under variable conditions to succeed (Falk 1992). They are also uncertain because little is usually known of the biology of the species being reintroduced, such as genetic population structure, pollinators, and requirements for germination or seedling establishment. Therefore, reintroductions are likely to require "adaptive management" tactics in horticultural and ecological management practices, and much experimental replication (trial and error). Reintroduction may also depend on developing sound practical understanding of horticultural considerations (propagation, transplanting techniques, soil preparation, seasonal timing; Guerrant 1996) and ecology (local variation in microhabitat preferences, adult and seedling habitat, pollinators, pathogens, herbivory) for individual species. Important local ecological information may be essential for successful reintroduction, but is seldom available in the biological literature.

Not all plant species reintroductions are difficult and failure-prone, however. Some reintroduced native species appear to be naturally robust colonizers of early-succession habitats, and sometimes establish readily in suitable conditions. Many native coastal dune species such as sea-rye or dunegrass (*Leymus mollis*), sand verbenas (*Abronia latifolia* and the uncommon introgressant *Abronia umbellata*), beach strawberry (*Fragaria chiloensis*), coyote-brush (*Baccharis pilularis*), and beach evening-primrose (*Camissonia cheiranthifolia*) fit this category. They spontaneously colonize restoration sites as well as degraded habitats. Many other native shrubs, grasses, and creeping herbs, both widespread and uncommon taxa, can be robust colonizers of suitable habitat. Uncommon hemiparasitic[2] paintbrushes (*Castilleja wightii* and *Castilleja affinis* ssp. *affinis*), which are reputedly difficult to cultivate, spontaneously colonize iceplant-covered roadway medians and roadsides and road cuts from San Francisco to Montara, San Mateo County (P. Baye, pers. observ. 1998-1999). Even the endangered San Francisco lessingia shows opportunistic “weedy” tendencies in disturbed sandy areas.

Of particular concern is the provenance of stock populations for reintroduction (Guerrant 1992, 1996; Knapp and Rice 1994; Lesica and Allendorf 1999). If local populations are confirmed to be extirpated, or are severely depleted, supplemental populations should be sought from closely similar ecological conditions (soil type, aspect, exposure) from the closest populations, in view of relevant mechanisms and pathways of dispersal. If source populations are themselves extremely depleted in numbers (and presumably, though not necessarily, genetic diversity),combining mixed founders from different suitable source populations should be evaluated (Lesica and Allendorf 1999). Each species would require careful individual evaluation for optimal reintroduction strategies, including surveys for remnant local and potential offsite

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[2] Hemiparasitic: a plant that parasitizes other plants by attaching to their roots, but nevertheless has photosynthetic leaves of its own.

source populations, and propagation or transplanting techniques. These assessments and plans should be implemented in restoration and reintroduction projects aimed at listed species.

1. Franciscan Manzanita, *Arctostaphylos franciscana* Eastwood

Franciscan manzanita (*Arctostaphylos hookeri* G. Don ssp. *franciscana* (Eastwood, Munz) is a low, spreading to ascending evergreen shrub in the heath family (Ericaceae) (Figure 9). It is extinct in the wild, but formerly occurred mixed with Raven's manzanita on serpentine outcrops at three of four historically recorded localities. It is the diploid (n = 13) ecological equivalent of the tetraploid (n = 26) Raven's manzanita. Recent molecular genetic data suggest that it is possibly a parent species, or a derivative of a parent species, of Raven's manzanita (M. Vasey, pers. comm. 1998; Markos *et al*. 1999). These data also suggest that Raven's and Franciscan manzanitas are not closely related to *A. hookeri* subspecies of the Monterey coast, but probably constitute a distinct species complex also including Tamalpais manzanita (*Arctostaphylos montana* Eastwood, treated as *Arctostaphylos hookeri* ssp. *montana* by Wells [1993]). Franciscan manzanita was once a candidate for Federal listing (U.S. Fish and Wildlife Service 1980), but was not listed because no natural populations existed in the wild.

Mixed wild populations of Franciscan and Raven's manzanita occurred at the Laurel Hill Cemetery, the Masonic Cemetery, Mt. Davidson (Howell *et al*. 1958, U.S. Fish and Wildlife Service 1984), and possibly the Haight/Laguna Street site reported by Behr (1892) as well. At Laurel Hill, Franciscan manzanita was allegedly less abundant than Raven's manzanita (Roof 1976), where both associated with coast live oak (*Quercus agrifolia*), blue-blossom (*Ceanothus thyrsiflorus),* and coyote brush (*Baccharis pilularis*), according to Wieslander's herbarium collection (*Wieslander 838*, 27 October 1938). A collection label by L. Edmonds from the same locality (February 15, 1958) noted that it grew "in leafmold on serpentine outcrop." Behr (1892) referred to the 1850's occurrence of the "tall form of Manzanita still growing so abundantly on the slopes of Talmalpais" (*Arctostaphylos montana* Eastwood, considered also by Markos *et al*. [1999] to be closely related to Raven's manzanita) at the site of the Protestant Orphan Asylum. Brandegee (1892) cited the manzanita at this site as "*Arctostaphylos pungens* HBK," located at Laguna and Haight streets. The

San Francisco "*Arctostaphylos pungens*" of these authors is interpreted as either Franciscan manzanita, or mixed populations of this species and Raven's manzanita, in sheltered conditions that promote the growth of tall, branched plants (U.S. Fish and Wildlife Service 1984). Like Raven's manzanita, Franciscan manzanita is endemic to bedrock outcrops (primarily serpentine, but including greenstone, and likely mixed Franciscan rocks) in San Francisco.

While Franciscan manzanita has been extinct in the wild since the mid-20th century, up to three apparently distinct clones are maintained in cultivation. Differences between clones persist after propagation, suggesting that they are genetic individuals (D. Mahoney, pers. comm. 1998). Roof (1980) reported that he salvaged plants of Franciscan manzanita from the Laurel Hill site between 1938 and 1940, possibly multiple clones, from which modern collections are derived. These cultivated plants vary in degrees of prostrate and ascending growth habits, and are less susceptible to twig blight than Raven's manzanita in years of high rainfall (P. Baye, pers. observ. 1997-1999). The plants are propagated by vegetative cuttings with moderate difficulty but are easily cultivated, and thrive on neglect after they are established on a wide range of substrates, including dune sand in Strybing Arboretum, not a natural substrate for this shrub. Successful growth on substrates markedly different from serpentine suggests good soil adaptability and a high potential for reintroduction on various substrates. Franciscan manzanita also sets viable seed (possibly hybrid) that can be propagated as well, reportedly forming highly variable progeny (D. Mahoney, pers. comm. 1998).

The historic association between the two endemic San Francisco manzanitas at most interior historic San Francisco localities (not the Presidio, which is outside the known range of Franciscan manzanita) suggests that they should be reintroduced together at new (or formerly occupied) sites to allow for the possibility of rare hybrids and interspecific gene flow in the continued evolution of the complex, and to allow for other ecological interactions between these similar species. Reintroduced plants should be propagated only from either clones or seed from controlled pollination of inbred lines of Franciscan manzanita, if feasible. Reintroduction may be attempted on both serpentine substrates and other types of Franciscan rocks.

2. Franciscan Thistle, *Cirsium andrewsii* Gray

Franciscan thistle is a coarse, spiny, short-lived perennial herb in the aster family (Asteraceae), growing from 0.6 to 2.0 meters (2 to 6 feet) tall when mature (Figure 9). It grows from a large low rosette when juvenile. Franciscan thistle is rare, found in small and often isolated populations on wet soils and seeps of coastal bluffs, streams and canyons (Munz 1959, Keil and Turner 1993). At the Presidio, populations of Franciscan thistle appear to have an affinity for vegetation gaps in both undisturbed and disturbed soils and successional habitats within low-growing coastal scrub (P. Baye, pers. observ. 1998). In some populations of the Marin Headlands, this species appears to regenerate in relatively closed wet coastal scrub vegetation. Hybrids with brownie thistle (*Cirsium quercetorum*) have been reported from Point Reyes (Howell 1949).

Franciscan thistle is reported to range from northern San Mateo (Thomas 1961) to Sonoma Counties (Munz 1959),but no collections from Sonoma County were reported in the flora of Sonoma County (Best *et al*. 1996), and it is not reported in the flora of San Bruno Mountain (McClintock *et al*. 1990), which includes the most likely remaining habitat in San Mateo County. Only a few historic and current populations in Marin County have been reported: Rodeo Lagoon (apparently extirpated), Tennessee Cove/Valley (confirmed 1985 by Golden Gate National Recreation Area staff), Gerbode Valley (reconfirmed by Golden Gate National Recreation Area staff early 1999), Dillon Beach, and Point Reyes. San Francisco populations have been recorded only by J. Howell in the Presidio and near Lake Merced. Franciscan thistle was historically collected east of Lake Merced in wet ground near a willow grove, and in serpentine seeps at Fort Point, Presidio (Howell *et al*. 1958). Three colonies occur between Fort Point (on serpentine bluffs immediately east of the Golden Gate Bridge) and Battery Boutelle, all on the marine bluffs. The Fort Point colony is in decline (S. Farrell, pers. comm. 1999). A small but expanding population, located in 1998 (at least five individuals large enough to flower, two of which flowered in 1999; P. Baye unpublished data 1998-1999), is established and managed near and in a mudslide on serpentine bluff seeps below Fort Scott (Battery Boutelle). Another colony of about five plants was located in late summer of 1999 (M. Chasse and P. Brastow, pers. comm. 1999). The distribution and abundance of Franciscan thistle needs reevaluation. This plant may be considerably rarer than has been presumed based on historic localities. Many of its historic localities have not been surveyed recently and may be extirpated. Surveys are particularly needed in San Mateo County.

3. San Francisco Spineflower, *Chorizanthe cuspidata* Watson

San Francisco spineflower is a prostrate annual in the buckwheat family (Polygonaceae) (Figure 9). It bears flowers and fruits with persistent spiny bracts that readily attach to fur and fabric, facilitating seed dispersal. San Francisco spineflower is ecologically restricted to sparse, open vegetation on sand or sandy soils. Taxonomic treatment of this species, and its delimitation from closely related species, has changed over decades, and is not consistent in variously dated floras (Howell 1949, Thomas 1961, Hickman 1993). Nearly all populations occur on coastal sand dunes; a few occur on weakly consolidated sandstone. Within its narrow geographic range along the immediate coast from San Mateo County to southern Sonoma County, it occurs in local abundance in coastal sands of Bodega Head, Dillon Beach, Point Reyes, and southwestern portions of the Presidio in San Francisco (Hickman 1993, Best *et al.* 1996, P. Baye unpublished data 1992-1999). It has been reported historically from near Santa Cruz (Thomas 1961). In San Francisco it has been recorded at Baker Beach, near the Cliff House, Richmond District, Lake Merced (Fort Funston), and Presidio (Howell *et al*. 1958). Because of the dispersal and colonization ability of this species, it is expected to have relatively dynamic local population distribution. Brandegee (1892) described it as widespread in the western part of the City. The type locality is San Francisco. It is recognized as a species of concern in the Recovery Plan for Seven Coastal Plants and the Myrtle's Silverspot Butterfly (U.S. Fish and Wildlife Service 1998*b*).

4. Round-headed Chinese Houses, *Collinsia corymbosa* Buist ex Graham

This showy annual member of the snapdragon family (Scrophulariaceae) was collected in San Francisco in the late 19th and early 20th century. According to Wood (1996) it was collected at Mountain Lake (1891), Lake Merced (1900), and Ocean View (1892), which are all general sandy localities known to have supported San Francisco lessingia. Collections at the California Academy of Sciences include Presidio golf links (former dunes) and unspecified localities within San Francisco. Round-headed Chinese houses was historically reported from Bolinas Lagoon, and was collected by

A. Eastwood at Point Reyes (Howell 1949), but has not been confirmed in recent decades. The species is not reported from Sonoma County according to Best *et al*. (1996), but Skinner and Pavlik (1994) identify a need for verification of an historic “Russian colony” collection (possibly either at Fort Ross, Sonoma County, or obtained from then-unnamed coastal localities by collectors stationed there).

Munz (1959) described round-headed Chinese houses as restricted to sandy coastal environments from Humboldt to San Francisco Counties. It is related to, and may intergrade with, the similar white Chinese-houses (*Collinsia bartsiifolia* [spelled *C. bartsiaefolia* in the older literature]) (Howell *et al*. 1958). Jepson (1925) reported it only from the central Mendocino coast (presumably Tenmile Dunes). It is presumed to be extirpated in San Francisco. The only population that has recently been verified is in dunes near Fort Bragg to the Tenmile River, Mendocino County; this population is possibly the only one remaining anywhere. Other historic localities in Humboldt County urgently need verification. This species is threatened by incipient invasion by European beachgrass at Tenmile Dunes, a weed that could permanently eliminate its habitat if allowed to spread (U.S. Fish and Wildlife Service 1998*b*). Round-headed Chinese houses is also vulnerable to random extinction because of small population size and extremely narrow geographic range.

5. San Francisco Wallflower, *Erysimum franciscanum* Rossbach

San Francisco wallflower is a short-lived subshrubby perennial herb in the mustard family (Brassicaceae) with showy, sweet-scented cream to cream-yellow flowers (Figure 9). In San Francisco, it is ecologically wide-ranging in relatively open, low, or sparse ground layer vegetation of rock outcrops, serpentine soils, and dunes (P. Baye, pers. observ. 1990's). San Francisco wallflower was recorded historically in San Francisco at Baker Beach, Point Lobos (1912), Lone Mountain, Sunset Heights, Laguna Honda (1933), and Lake Merced (1901) (Howell *et al*. 1958, Wood 1996). Remnant populations occur at the Sunset Heights Dune remnants and Franciscan outcrops, Baker Beach, and Fort Funston (Golden Gate National Recreation Area unpublished data; P. Baye, pers. observ. 1998). Nearby scattered populations occur on San Bruno Mountain (McClintock *et al*. 1990), along Highway 1 from Pacifica and

Montara, and in the Marin Headlands (P. Baye, pers. observ. 1990's). It is rare in Marin, Santa Clara, Santa Cruz, San Mateo, and Sonoma Counties (Skinner and Pavlik 1994).

6. San Francisco Gumplant, *Grindelia hirsutula* Hook. & Arn. var. *maritima* (E. Greene) M. A. Lane

San Francisco gumplant is a prostrate subshrub of the aster family (Asteraceae) (Figure 9). It occurs on serpentine and sandstone coastal bluffs, and sometimes on rock outcrops away from the immediate coast, where vegetation cover is sparse and open. San Francisco gumplant is variable in its morphological traits, and many populations are somewhat ambiguous taxonomically (Lane 1993). Another prostrate gumplant that grows on coastal bluffs and rocks within San Francisco gumplant's range is coastal gumplant (*Grindelia stricta* ssp. *platyphylla*), which has broader, rounded leaves, and pappus awns (small barb-like appendages on seed-like dry fruits) that are less than 0.3 millimeters (0.01 inch) long and lack teeth (Lane 1993).

San Francisco gumplant is uncommon to rare in Monterey, Marin, Santa Cruz, San Luis Obispo, and San Mateo Counties; current localities need verification (Skinner and Pavlik 1994). In San Francisco it appears to occur relatively early in succession after episodes of bluff erosion (P. Baye, pers. observ. 1990's). In San Francisco, it was historically recorded on Presidio bluffs, Point Lobos, Lake Merced, Laguna Honda, and Twin Peaks (Howell *et al*. 1958, Wood 1996). A local form with hairy stems (formerly recognized as *Grindelia maritima* (E. Greene) Steyermark forma *anomala* Steyermark) co-occurred with typical *Grindelia hirsutula* var. *maritima* at Laguna Honda, Twin Peaks, and San Miguel Hills (Howell *et al.* 1958). Currently it occurs with Raven's manzanita (partly due to planting), and numerous colonies occur along the serpentine bluff area of the Presidio. Apparent hybrids occur in northern San Mateo County, according to McClintock *et al.* (1990).

7. Diablo Helianthella, *Helianthella castanea* E. Greene

Diablo helianthella is a taprooted sunflower-like perennial herb in the aster family (Asteraceae). It grows from a caudex (swollen trunk-like base bearing multiple herbaceous shoots). It resembles common mule-ears (*Wyethia* spp.) in general appearance. The species is rare, occurring in open grassland on interior hills of the east Bay and San Francisco Peninsula. It is extirpated in San Francisco (Wood 1996) where it formerly occurred near Ocean View, southeastern San Francisco Hills and Bayview Hills in the late 19th century (Brandegee 1892, Howell *et al*. 1958). It is not known which specific local plant associations included Diablo helianthella, but grasslands and sparse scrub on thin, rocky soils (such as bedrock outcrop slopes) are probable candidates. The nearest reported population occurs on San Bruno Mountain in Brisbane (McClintock *et al*. 1990).

8. Evax, *Hesperevax sparsiflora* (A. Gray) E. Greene

Evax is a short (less than 15 centimeters [5 inches]) woolly-leaved annual herb in the aster family (Asteraceae) with multiple ascending to erect stems. On the San Francisco Peninsula and the adjacent region, evax occurs on rocky, thin soils and grasslands (Thomas 1961). In San Francisco, it occurred primarily on serpentine soils (Howell *et al*. 1958). The treatment in the Jepson Manual (Hickman 1993) by Morefield (1993) divides the species into two varieties: plants from serpentine are *Hesperevax sparsiflora* var. *sparsiflora* while plants from sandy bluffs and flats are designated as var. *brevifolia*, which is described as "uncommon." The two varieties of evax are separated by characters with overlapping variation (leaf length, relative leaf roundness, hairs), so there may be some question regarding the varietal identity of the San Francisco plants. Previously, San Francisco plants had been recognized by Howell *et al.* (1958) as *Evax sparsiflora* (A. Gray) Jepson without varietal distinctions. The historical distribution of the San Francisco plants is from the Presidio, Potrero Hills, Hunters Point, and McLaren Park (Howell *et al.* 1958, Wood 1996) – all localities including serpentine outcrops, and all but the Presidio lacking sandy substrates, so one would expect these plants to be assigned to var. *sparsiflora*. Wood (1996) instead assigned the San Francisco plants to *Hesperevax sparsiflora* var. *brevifolia*.

The contemporary local abundance of evax on the San Francisco Peninsula is unknown, but it may now be locally extirpated. Additional survey information on this species is needed in this region.

9. Kellogg's Horkelia, *Horkelia cuneata* Lindley ssp. *sericea* (A. Gray) Keck

Kellogg's horkelia is a resinous-scented perennial herb in the rose family (Rosaceae) that grows from a branched semi-woody base. Its leaves are conspicuously covered with silky pubescence, and glands are inconspicuous or absent. This and similar species (Marin horkelia [*Horkelia marinensis*] and wedge-leaf horkelia [*Horkelia cuneata* ssp. *cuneata*]) are found on sandy soils and old stabilized dunes with relatively open vegetation (P. Baye, pers. observ. 1990's). Kellogg's horkelia is presumed to be extirpated in San Francisco, Marin, and Alameda Counties (Skinner and Pavlik 1994), and is rare on sandy soils of the central coast (Monterey, San Luis Obispo, and Santa Barbara Counties; Hoover 1970, Matthews 1997). One occurrence in San Mateo County on part of San Bruno Mountain (Daly City, on a remnant sand slope in a residential area) is presumed to be the last in the San Francisco Bay area (Skinner and Pavlik 1994). In San Francisco, Kellogg's horkelia was collected in the early 20th century (variously as *Potentilla lindleyi* var. *sericea* (A. Gray) Howell, or *Potentilla kelloggii* Jepson) from dunes of the western part of the City at Point Lobos, Lake Merced, Sunset Heights, Ocean View (Howell *et al.* 1958), all known historic localities of San Francisco lessingia. Additional survey information on this species is needed in this region.

10. Large-flowered Linanthus, *Linanthus grandiflorus* (Benth.) E. Greene

Large-flowered linanthus is a small, showy-flowered annual herb in the phlox family (Polemoniaceae). Large-flowered linanthus has white to pink flowers with short (5 to 6 millimeters, about 0.2 inch) tubes (distinguishing it from common linanthus (*Linanthus parviflorus*), another species also found on old dunes), displayed in head-like clusters (Patterson 1993). It is an uncommon species, typically found in sandy grasslands with low, sparse vegetation. Within the region it is found mainly along crests of the Santa Cruz Mountains (Thomas 1961) and rarely in Marin County on old dunes in Point Reyes (Howell 1949), where it still occurs locally in older dune soils, and associates with the endangered Sonoma spineflower (*Chorizanthe valida*)(P. Baye unpublished data 1999) and the rare Marin horkelia (*Horkelia marinense*). Historic San Francisco collections are known from the Presidio (1894) and near Lake Merced (1891) (Howell *et al*. 1958, Wood 1996), localities likely to include old dune or sandy grasslands. No recent collections have been made in San Francisco or San Bruno

Mountain, and it is quite likely now extirpated on the Peninsula. Additional survey information on this species is needed in this coastal region.

11. Curly-leaved Monardella, *Monardella undulata* Benth.

Curly-leaved monardella is a strongly scented (pungent pennyroyal-like fragrance) annual herb in the mint family (Lamiaceae) with sticky-glandular flowerheads and purple flowers (Figure 9). It is uncommon but locally abundant, usually found along the central coast in old dunes, or similar sandy soils in inland and coastal plant communities. It ranges from Sonoma to Santa Barbara Counties (Munz 1959). The only coastal population to be recently confirmed north of Monterey Bay in coastal dunes occurs in coastal dunes at Point Reyes, where it is widespread and locally abundant in stabilized older dunes, especially in years of high rainfall (P. Baye unpublished data 1990-1999). The only known locality of this species on the San Francisco Peninsula was in San Francisco, where a single Brandegee collection (probably late 19th century) was made at Lake Merced dunes near what is now Fort Funston (Brandegee 1892, Howell *et al*. 1958). It is now extirpated on the San Francisco Peninsula, although suitable habitat persists at Fort Funston near the historic locality.

12. Greene's Popcornflower, *Plagiobothrys reticulatus* (Piper) I. M. Johnson var. *rossianorum* I. M. Johnson (= *Plagiobothrys diffusus* E. Greene)

Greene's popcornflower is a low annual herb in the borage family (Boraginaceae). The treatment of *Plagiobothrys* by Messick (1993) in the Jepson Manual interpreted the endemic San Francisco (Presidio) population of Greene's popcornflower (*Plagiobothrys diffusus*) as a variant within *Plagiobothrys reticulatus* var. *rossianorum*. The taxonomy of this group is problematic. Thomas (1961) placed *Plagiobothrys reticulatus* within *Allocarya californica*, and cited only one locality north of Santa Cruz; he attributed *Plagiobothrys diffusus* only to San Francisco. Skinner and Pavlik (1994) reported that Greene's popcornflower is known from only six localities, in Santa Clara and San Francisco Counties. Whatever the identity of this ambiguous set of taxa, they appear to be quite rare. Greene's popcornflower is extirpated (possibly altogether extinct, depending on taxonomic interpretation) in San

Francisco, where it was reported only from "clayey flats near Mountain Lake" as recently as the 1930's (Howell *et al*. 1958, Wood 1996).

Greene's popcornflower was reported from southwest Farallon Island from 1978-1985, where it occurred in local abundance between residences (apparently extirpated since then), but only photographs, no voucher specimens, are available to confirm this occurrence (Point Reyes Bird Observatory file information; M. Coulter, pers. comm. 1997). Southwest Farallon Island was supplied with imported garden soil for residential gardens during the last century, possibly from the Presidio, which may have been the source of the population. Though not observed since 1985, it may possibly remain as dormant seed in soil there. Recent reports of this species in dune slacks and other seasonal wetland habitats of Point Reyes await verification. Additional survey information on this species is needed, particularly Point Reyes and seed bank sampling from the Farallons.

13. San Francisco Campion, *Silene verecunda* S. Watson ssp. *verecunda*

San Francisco campion is a perennial herb in the pink (carnation) family (Caryophyllaceae). It grows from a branched semi-woody base that bears erect stems supporting terminal clusters of small but showy white to pink flowers. It occurs only between San Francisco and Santa Cruz County, and is reported from fewer than 20 localities (Thomas 1961, Skinner and Pavlik 1994). Wilken (1993) in the Jepson Manual interpreted these plants as a possibly indistinct variant of ssp. *platyota*, which is widely distributed. In San Francisco it was historically reported or collected from Lands End, Sunset District dunes, and Lake Merced (Fort Funston) dunes (Howell *et al*. 1958). It is not known to grow on coastal dunes elsewhere in California. Small native remnant populations currently occur in San Francisco on dunes above Baker Beach, where the population has been artificially augmented. It has also been reintroduced to restored dunes near Lobos Creek and upslope from the natural Baker Beach population. A second population is reported from Mt. Davidson at the southeastern part of the City (Wood 1996). The type locality of the subspecies is San Francisco.

14. Seashore or Coast Starwort, *Stellaria littoralis* Torrey

Seashore starwort is a coarse colonial perennial herb in the pink (carnation) family (Caryophyllaceae) (Figure 9). It grows from tough, elastic creeping rhizomes and has lax, slender, flexible stems that climb over adjacent vegetation. It occurs in moist or wet sandy coastal soils, mostly in moist dune slacks or seeps in sandstone bluffs and ravines. San Francisco is the historic southern limit of the species, which ranges north to Mendocino County (Smith and Wheeler 1990-1991). It is rare, though locally abundant, throughout its historic range, and is known from a few populations at Dillon Beach (Brazil Beach), Point Reyes grassland swales (Howell 1949, P. Baye unpublished data 1990's), Bodega Head dunes (P. Connors unpublished data 1998, Best *et al*. 1996), and Manchester Beach dunes (Mendocino County; Smith and Wheeler 1990-1991). It is extirpated in San Francisco, where it was historically recorded from wet sandy soil near Lands End (Howell *et al*. 1958). These localities were probably thin dune deposits over seeps in Franciscan bedrock or Colma formation sands. The nearest populations are at Point Reyes, the type locality and center of abundance (from Tomales Point to Limantour Estero in dune slacks and wet grassland swales).

15. Dune Tansy, *Tanacetum camphoratum* Less.

Dune tansy is a robust, tall, erect, rhizomatous and strongly scented perennial herb in the aster family (Asteraceae) (Figure 9). Its lax, coarse, spreading above-ground stems and below-ground rhizomes form colonies in stable and semi-mobile coastal dunes. Dune tansy (*Tanacetum camphoratum*) was distinguished from Douglas' tansy (*T. douglasii* DC.), which ranges from Mendocino County to British Columbia (Munz 1959), by the absence of conspicuous short yellow petal-like ligulate (ray) flowers (present in populations from Mendocino and north) and the presence of dense white-woolly and gray-green leaves.The only natural populations of the typical white-woolly form with highly reduced or absent ray florets today occur in dunes at San Francisco, Dillon Beach (Marin County) and Manchester Beach (Mendocino County) (P. Baye unpublished data 1997-2001). Dune tansy from San Francisco was recently introduced at Linda Mar Beach, Pacifica, San Mateo County. Both taxa have recently been treated as *Tanacetum camphoratum* without even varietal distinction (Kyhos and Raven 1982, Smith 1986, McClintock 1993). This taxonomic revision made the rare white-woolly, “rayless”, geographically discrete southern populations merely an extension of a single widespread northern coastal species. More detailed and comprehensive study of variability within and between populations in California is needed to improve taxonomic understanding of dune tansy.

Dune tansy was formerly common within the western parts of the San Francisco dune system, occurring as far east as Buena Vista Park, and west through Golden Gate Park (Brandegee 1892, Howell *et al*. 1958). It is also evident in historic photographs of western San Francisco (G. Gaar unpublished photographic archives 1999). Today the species occurs only on dunes at Baker Beach, sandy slopes near the Cliff House and Sutro Heights, at all three Sunset Heights dune remnants, and around Fort Funston dunes. It was recently reintroduced to Crissy Field dunes (P. Baye unpublished data 1997-1999).

16. San Francisco Owl’s-clover, *Triphysaria floribunda* (Benth.) Chuang and Heckard (= *Orthocarpus floribunda* Bentham)

San Francisco owl’s-clover is a very rare showy annual hemiparasitic member of the snapdragon family (Scrophulariaceae). Its habitat is coastal grassland, often on serpentine or sandy soil, in Marin, San Francisco, and San Mateo Counties (Howell 1949, Howell *et al*. 1958, Thomas 1961, Skinner and Pavlik 1994). In San Francisco, it had been known until recently only as a small intermittent population near the Raven’s manzanita parent clone. In some years, no plants appear there, followed by years of small populations. It was recently rediscovered on an unirrigated portion of a rough lawn near the Log Cabin, Presidio, on graded serpentine soil (M. Chasse, pers. comm. 2001), near or on an historic locality. Historically, San Francisco owl’s-clover was collected in San Francisco above Fort Point, Baker Beach, Presidio (1902), and Lake Merced (1907) (Howell *et al*. 1958, Wood 1996). These localities included coastal dunes, serpentine outcrops, and older sandy soils. Otherwise it is recently confirmed only from the Point Reyes Peninsula (B. Moritsch, pers. comm. 1999), and remains precariously close to extinction. The nearest historic populations from San Bruno Mountain have not been observed since the 1960's (McClintock *et al*. 1990).

C. Species of Local and Regional Conservation Significance

The following species are either in decline in a significant portion of their ranges, or have become extirpated or rare in coastal dune and serpentine outcrop vegetation on the San Francisco Peninsula. Some local populations may represent significant ecological or geographic variants of more widespread species. Some taxa are suspected of being in decline, but lack reliable and recent records of occurrence. These plants warrant scrutiny to avoid significant decline in geographic range and abundance. Conservation of genetic variation among populations of relatively widespread species is beneficial, and is efficient compared to intervening after a species becomes rare due to artificial factors (Millar and Libby 1991). Like the species of concern, these selected species of local and regional interest warrant special attention in surveys and restoration plans that are conducted as recovery actions for listed species. These selected species in some cases may be considered likely to become species of concern, at least within the portion of their range covered in this recovery plan.

1. Pink Sand-verbena (introgressant) *Abronia umbellata* Lam. ssp. *umbellata* (introgressive with *Abronia latifolia*)

Typical pink sand-verbena (*Abronia umbellata*) is a fleshy annual herbaceous plant in the four o'clock family (Nyctaginaceae) (Figure 9). It has a prostrate and spreading growth habit, slightly sinuate green leaves, and abundant umbels of showy pink flowers. The historic range of typical pink sand-verbena is Sonoma County to Baja California (Munz 1959, Spellenberg 1993*a*). The species as a whole is inconsistently treated in regional floras as either an annual (Munz 1959, Spellenberg 1993*a*, Skinner and Pavlik 1994) or perennial (Jepson 1911, Abrams 1944, Munz 1959, Hoover 1970). Also, many poorly defined varieties were formerly recognized (Tillett 1967). This taxonomic ambiguity may be due to confusion between typical populations and widespread introgressive (natural hybrid backcrosses) populations, often with yellow sand-verbena (*Abronia latifolia*) (Tillett 1967). Introgression of yellow sand-verbena into pink sand-verbena is widespread in California, while introgression of pink sand-verbena into yellow sand-verbena is rare (Tillett 1967).

Introgressive populations of pink sand-verbena have been identified from San Francisco, San Mateo, Marin, and Sonoma Counties (Tillett 1967, and California Academy of Sciences herbarium collection annotations by Tillett, 1961). Populations from San Mateo beaches and low foredunes northward to Marin County are currently very uncommon and small, and appear to be predominantly perennial introgressive forms. Typical pink sand-verbena is currently common only in stable dune scrub from the Monterey Bay area southward (P. Baye, pers. observ. 1995-1999). Introgressive or hybrid populations are commonly facultative perennials and occur on beaches and foredunes, like yellow sand-verbena, while the nearest populations of typical annual pink sand-verbena in Monterey Bay usually occur in stabilized older dunes (P. Baye, pers. observ. 1997-1999). Traits that indicate introgression or hybridization with yellow sand-verbena include fragrant flowers, pale pink to pale salmon or yellowish-pink flowers (sometimes with yellowish eye-spots), perennial growth, and thinner gray-green leaves. The rare north coast pink sand-verbena (*Abronia umbellata* ssp. *breviflora* [Standley] Munz) of northern California beaches, though treated as a distinct subspecies, is also considered to be the stabilized product of introgression with yellow sand-verbena (Tillett 1967).

In San Francisco, "*Abronia umbellata*" as reported by Brandegee (1892) and Howell *et al*. (1958) occurs only at the low foredunes and beach at Crissy Field, in the Presidio (a site evidently not surveyed by Tillett [1967]). This distinctive population occurs mixed with yellow sand-verbena, and appears to consist exclusively of introgressive individuals, and possibly some hybrids. Some individuals here approach ssp. *breviflora* (P. Baye unpublished data, 1999). Historically, pink sand-verbena (probably also introgressant plants) was also reported from a beach in southeastern San Francisco near Hunters Point (Brandegee 1892). It was also collected from Ocean Beach near Golden Gate Park by Peter Rubtzoff in 1959 (CAS538598), and from an unspecified San Francisco locality by Kellogg in 1868-1869 (CAS132847), annotated by Tillett as a mixed collection of the typical species and introgressants. Introgressants have also been collected from Lands End (Tillett 1967).

The introgressant pink sand-verbena of Crissy Field is protected by the Golden Gate National Recreation Area, and is also propagated and outplanted locally in local dune restoration (J. Cannon and M. Wadsworth, pers. comm. 1997-1999). The natural population of perennial foredune clones here is highly variable: plants are generally perennial with wavy-margined gray-green leaves and flowers variously lightly scented or unscented by day, ranging from pale salmon with yellow highlights and highly scented to rich magenta with minimal scent. The population is apparently stabilized and sexually reproducing: it has been present at this locality since the late 19th century (Brandegee 1892), and seedlings spontaneously occur some years at Crissy Field (P. Baye, pers. observ. 1993-1998). Field-collected seed germinate readily in the Presidio nursery (M. Wadsworth, pers. comm. 1998). Nursery propagation by seed may be unconsciously selective, however. Nursery-grown transplants appear to have high frequencies of unscented, deeper pink-flowered genotypes that are closer to typical pink sand-verbena than the local old intermediate forms.

Most foredune habitat at Ocean Beach is probably too unstable for reintroduction of pink sand-verbena introgressants, but suitable habitat exists at the restored bluff-top foredunes at southern end of Fort Funston.

2. Coast Rock-cress, *Arabis blepharophylla* Hook. & Arn.

Coast rock-cress is a perennial herb in the mustard family (Brassicaceae). It forms clumps of vegetative rosettes that develop flowering shoots in late winter and early spring. Selected forms of the species are cultivated as an ornamental perennial for purple spring-blooming flowers. Coast rock-cress naturally occurs on outcropping bedrock along or near the coast, or among sparse vegetation or open soil of coastal bluffs from Santa Cruz to Sonoma Counties. It is uncommon to rare along the bluffs of the Golden Gate, particularly the Presidio serpentine bluffs (Golden Gate National Recreation Area, unpublished file information 1995). Local populations occur on San Bruno Mountain. Coast rock-cress is threatened by invasive species that colonize its naturally open habitats. Pampas (jubata) grass (*Cortaderia jubata*) and iceplant (*Carpobrotus edulis*) are examples of these aggressive types of invasive species. San Francisco is the probable type locality.

3. Nuttall's Milk-vetch, *Astragalus nuttallii* (Torrey & A. Gray) J. Howell var. *virgatus* (A. Gray) Barneby

Nuttall's milk-vetch is an uncommon to rare taprooted perennial herb in the pea family (Fabaceae) with low, sprawling or mounding stems (Figure 9). Like other milkvetches, it produces large, dry, papery-skinned, inflated, buoyant fruits (legumes) and small, hard seeds. This species typically grows in vegetation of sandy coastal bluffs, coastal scrub, and coastal dune scrub. The northern limit of the variety *virgatus* is Sonoma County (Salt Point, north of Gerstle Cove, where multiple colonies occur in grassland of a marine terrace near the bluff edge; Best *et al*. 1996, P. Baye, unpubl. data 2000). The reported southern limit of this variety is a coastal bluff south of Pomponio Beach, San Mateo County (CALFLORA 2001). The largest population occurs at Mori Point, Pacifica, San Mateo County, on ocean bluffs of a derelict quarry (P. Baye, unpubl. data 2001). Elsewhere in San Mateo County, Nuttall's milk-vetch occurs uncommonly in grassland and open sandy soils of San Bruno Mountain (McClintock *et al*. 1990), near Sweeney Ridge near Pacifica (M. Mencke, pers. comm. 1998), and on coastal bluffs near Pillar Point, San Mateo County (P. Baye unpublished data 1998-2001). It has been reported in Marin County as local and rare in coastal bluffs at Tomales Point, but has not recently been confirmed there (Howell 1949; P. Baye, pers. observ. 1990's).   Nuttall's milk-vetch is currently restricted in San Francisco to Fort Funston dunes and recent transplants to Crissy Field, Presidio (P. Baye, pers. observ. 2001). Historically it was collected at the Presidio (1900, 1894), Point Lobos (1912), Lone Mountain, and Lake Merced (1892) (Howell *et al*. 1958, Wood 1996). San Francisco is the type locality of Franciscan milkvetch (*Astragalus franciscanus* [Sheldon]), which has been placed in synonomy with *Astragalus nuttallii* var. *virgatus*. The similar variety *nuttallii* (distinguished by its grayish hairy leaves and looser inflorescence; Munz 1959, Spellenberg 1993*b*) ranges from Monterey Bay south to Point Conception (Munz 1959).

4. California Saltbush, *Atriplex californica* Moquin

California saltbush is a low perennial herb in the goosefoot family (Chenopodiaceae). It grows in clumps or mats branching from a thick, deep taproot, and has small lance-shaped gray-green to greenish white-mealy leaves. Its habitats include coastal dunes, coastal bluffs, and coastal salt marsh edges. It is uncommon north of Monterey Bay, ranging north to northwest Sonoma County (Taylor and Wilken 1993, Best *et al*. 1996), where a small, usually vegetative colony grows on sandstone outcrops in coastal cliffs near Gerstle Cove, Salt Point.   In west Marin County, it generally occurs along the upper edges of sandy salt marshes, and on coastal sandstone bluffs. From Monterey Bay south, it occurs in stable dunes and sandy bluffs in areas of predominantly low vegetation. Historically it occurred on bluffs and dune flats in western San Francisco (Howell *et al.* 1958). Locally it is currently restricted to small remnant populations at Fort Point (on erosional serpentine bluffs, an atypical habitat) and larger populations near Point Lobos (on Colma Formation sands and Franciscan sandstone). It is extirpated in San Francisco dune remnants and salt marsh edges, and is not reported from dunes north of Monterey Bay. Nearest recently confirmed populations occur on sandy bluffs in San Mateo County (Rockaway Head and Mori Point, Pacifica) and along salt marsh edges at Point Reyes (P. Baye unpublished data 1997-2001).

5. Indian Paintbrush, *Castilleja affinis* Hook. and Arn. ssp. *affinis* (coastal forms)

The taxonomy and identification of variable coastal indian paintbrush populations (*Castilleja* spp.) is complex. The Indian paintbrush of the serpentine bluffs and dunes of San Francisco was treated as Monterey Indian paintbrush (*Castilleja latifolia*) in the Flora of San Francisco (Howell *et al*. 1958). Typical *C. latifolia* has been narrowly interpreted as a species restricted to the vicinity of the Monterey Bay/Santa Cruz coast (Pennell 1951, Munz 1959, Chuang and Heckard 1993), but it has also been broadly interpreted as a variable species with many infraspecific taxa distributed over a wider geographic range (Jepson 1925, Howell 1949, Howell *et al*. 1958, Thomas 1961), including many taxa now placed in synonymy with coast Indian paintbrush (*C. affinis*) or Wight's Indian paintbrush (*C. wightii*) (Chuang and Heckard 1993). The taxonomy of all the perennial *Castilleja*s of the immediate central and northern California coast (*C. latifolia* and its former varieties, *C. wightii*, *C. mendocinensis*, *C. affinis* ssp. *litoralis* and ssp. *affinis* [including *C. inflata* Pennell]) has been variously interpreted throughout the 20th century (Jepson 1925, Howell 1949, Pennell 1951, Munz 1959, Chuang and Heckard 1993). The notorious taxonomic difficulties in the genus are due to high variability within species, hybridization, and polyploidy (Chuang and Heckard 1993).

Following the revised key to species of the realigned *Castilleja* by Chuang and Heckard (in Hickman 1993), plants from coastal bluffs and dunes in San Francisco, and herbarium sheets of most "*Castilleja latifolia*" from San Francisco at the California Academy of Sciences would be referred to coast Indian paintbrush (*C. affinis* ssp. *affinis*), but possibly intergrading toward Monterey Indian paintbrush

(*C. latifolia*) in some significant traits (P. Baye unpublished data 1999) (Figure 9). Intermediate plants referable to *C. affinis*, but closely approaching typical Monterey Indian-paintbrush are prevalent in dunes at Pescadero, San Mateo County (P. Baye unpublished data 1998-2001). The San Francisco (and Marin) coastal populations of coast Indian paintbrush are atypical for this species in significant vegetative morphological (mostly foliar) traits. Presidio serpentine bluff and Baker Beach dune populations appear morphologically indistinct. Presidio serpentine bluff and dune populations of coast Indian paintbrush have firm, thick membranous leaves (not fleshy as typical Monterey Indian paintbrush) that are mostly lanceolate (occasionally lance-ovate to oblong, much broader than typical coast Indian paintbrush), up to 7 centimeters (2.8 inches) long (cauline leaves typically 3 to 6 centimeters long [1.2 to 2.4 inches]), acute, more than 3 times longer than wide (often more than 5 times longer than wide), often involute or folded (abaxial surface outward), with relatively narrow to linear, acute lateral or terminal lobes up to one-third the length of the leaf (P. Baye unpublished data).

The San Francisco serpentine bluff and dune populations of coast Indian paintbrush are significant for their size, atypical traits, and wide ecological tolerance for extremes of exposure to salt spray and harsh, contrasting soil conditions. They apparently displace the common Wight's Indian paintbrush, the dominant Indian paintbrush of the northern San Mateo coastal bluffs and headlands. The occurrence of coast Indian paintbrush on serpentine soil here is significant: no Monterey Indian paintbrush collections from serpentine are reported (CALFLORA 1999), but another subspecies of *C. affinis*, the federally endangered Tiburon Indian paintbrush (*C. affinis* ssp. *neglecta*; U.S. Fish and Wildlife Service 1998*a*) is restricted to serpentine soils in Tiburon, less than 8 kilometers (5 miles) from the Golden Gate.

Howell (1949) also treated the similar coastal dune Indian paintbrushes of Point Reyes, formerly classified as *Castilleja inflata* Pennell, as variants of *C. latifolia*. Although much of the "*Castilleja inflata*" from spray-exposed Point Reyes localities more closely approaches Monterey *C. latifolia* in critical vegetative traits (oblong to ovate, blunt, succulent leaves; P. Baye unpublished data), Chuang and Heckard (1993) placed *C. inflata* in synonymy with *C. affinis* ssp. *affinis*. *C. affinis* ssp. *affinis* specimens similar to those of San Francisco also occur in coastal scrub at Point Reyes. Geographic and environmental variation in vegetative characters in the coastal

C. affinis - *latifolia* - *wightii* - *mendocinensis* complex may require more intensive sampling of populations for adequate taxonomic resolution.

Coast Indian paintbrush (*C. affinis* ssp. *affinis*) is a hemiparasitic perennial herb with a woody base, and a member of the snapdragon family (Scrophulariaceae). Coast Indian paintbrush grows in clumps (sometimes decumbent to ascending) about 0.3 meter (1 foot) tall in open coastal scrub vegetation on dunes and bluffs in San Francisco. It typically has abundant short axillary shoots on the coast from San Mateo County to Marin County. In late summer or fall after seeds have matured, it dies back to a woody base, and regenerates vegetatively during late winter when soil moisture, temperatures, and daylength increase. Seedlings often occur shaded under parent plants or leaf litter in years of ample rainfall. Nearly glandless (below the inflorescence, unlike glandular Wight's Indian-paintbrush), shaggy-hairy or bristly stems bear spikes of flowers beginning around March to April, and continue to appear intermittently through fall or winter. Conspicuous bracts (sheath-like leafy structures appearing below flowers) range in color from dull orange-red to brilliant scarlet in San Francisco; elsewhere they may occasionally include orange-yellow to salmon-yellow forms as well. Hummingbirds are presumably the principal pollinators.

Coast Indian paintbrush in San Francisco was reported historically as *Castilleja latifolia* from dunes and bluffs above Baker Beach, around Lake Merced (now Fort Funston area), Presidio (serpentine) bluffs from Fort Point to Lobos Creek, and from Sunset District dunes (Brandegee 1892, Howell *et al*. 1958). Modern dune populations are limited to Baker Beach (1 colony of fewer than 50 plants), Hawk Hill at Sunset Heights (approximately 4 plants in 1999), and restored and relict dunes of Fort Funston (variable populations, up to several hundred). The Presidio serpentine bluff population is relatively large (hundreds of plants some years). Population size varies significantly among years, but does not fluctuate as much as annual *Castilleja* species (P. Baye, pers. observ. 1990-1999). Coast Indian paintbrush has been propagated and planted at Fort Funston and Presidio dunes by the Golden Gate National Recreation Area (M. Petrelli and M. Wadsworth, pers. comm. 1997, 1998).

According to Pennell (1951) the type locality of coast Indian paintbrush is presumed to be San Francisco, and the type locality of Monterey Indian paintbrush is Monterey, but a San Francisco type locality of Monterey Indian paintbrush has also been attributed to Hooker and Arnott (Howell *et al*. 1958).

6. Banded (Broadleaf) Purple Owl's-clover, *Castilleja exserta* (A.A. Heller) Chuang and Heckard ssp. *latifolia* (S. Watson) Chuang and Heckard

Banded purple owl's-clover is a showy annual hemiparasitic herb in the snapdragon family (Scrophulariaceae) with spikes of purple, white, and yellow flowers (Figure 9). The subspecies *latifolia* (literally, "broadleaf") is restricted to sandy soils of coastal bluffs, coastal grasslands, and dunes of the north and central coast of California (Howell 1949, Thomas 1961, Best *et al*. 1996, Matthews 1997). It is now uncommon, but locally abundant over its range. In San Francisco, it is apparently either rare, intermittent (emerging only some years), or extirpated in coastal bluffs and dunes. Historically it was locally common at Lake Merced (1891, and as recently as the 1950's), and Ocean View (Howell *et al*. 1958, Wood 1996). It is reported as frequent in grasslands of San Bruno Mountain (McClintock *et al*. 1990). The nearest population on the immediate coast, which may be related to *C. exserta* ssp. *latifolia* (possibly related to *C. ambigua*) is at Rockaway Head, Pacifica (headland south of Rockaway Beach), where an anomalous form grows near the edges of a thin old dune soil (P. Baye unpublished data 1999). Banded purple owl's-clover also occurs in coastal dune grassland (older dune soils) at Point Reyes (south end of the outer dune system; Howell 1949, P. Baye unpublished data 1997-1999) and near Marina, Monterey Bay (Matthews 1997; P. Baye, pers. observ. 1997-1999). The species is a host plant for larvae of the threatened bay checkerspot butterfly (*Euphydryas editha bayensis*; U.S. Fish and Wildlife Service 1998*b*).

7. California Goosefoot, *Chenopodium californicum* (S. Watson) S. Watson

California goosefoot is a robust, coarse-leaved taprooted perennial herb in the goosefoot family (Chenopodiaceae). It occurs in a wide range of plant communities in relatively dry, open conditions. California goosefoot is infrequent to uncommon in central coastal scrub, but is widespread in California west of the Sierra (Munz 1959). It was historically uncommon or rare on the San Francisco Peninsula and San Bruno

Mountain (Howell *et al*. 1958, McClintock *et al*. 1990). The only known population in San Francisco persists as a few plants in relict dune scrub at one locality in San Francisco today within the Presidio (Rob Hill; M. Chasse, pers. comm. 1998). Historic records in San Francisco are limited to the Presidio, and a sandy hollow east of Lake Merced (Howell *et al*. 1958). The nearest known coastal dune populations are from San Mateo County (Half Moon Bay) and Point Reyes (P. Baye unpublished data 1998-1999). It is relatively more frequent in stable old dunes of Monterey Bay.

8. Davy's Clarkia, *Clarkia davyi* (Jepson) Harlan Lewis and M. Lewis

Davy's clarkia is an annual member of the evening-primrose family (Onagraceae). It has showy lavender-rose flowers, and a growth habit ranging from prostrate to ascending. Historically Davy's clarkia was known from dunes of the Sunset district, Lake Merced, and near Ocean View (Howell *et al*. 1958). It ranges from Del Norte County to San Mateo County along the coastal bluffs and sands (Munz 1959). It is more frequent in the northern part of its range. Its southern limit along the coast was reported by Howell *et al.* (1958) to be San Francisco, although it is reported as occasional on San Bruno Mountain (McClintock *et al.* 1990), and a disjunct population is reported from Santa Rosa Island (Lewis 1993).

9. California Croton, *Croton californicus* Muell. Arg.

California croton is a prostrate gray-green subshrub or shrub in the spurge family (Euphorbiaceae). It occurs on sandy soils (dunes, inland sand deposits, alluvial fans) from San Francisco south to Baja California, and inland to Arizona (Webster 1993). It is common in coastal dune scrub along the southern central coast (P. Baye unpublished data 1995-1999). North of the Monterey Bay region it is rare on the coast, collected or reported historically only from San Francisco (Thomas 1961). The northern coastal limit is in the remnant dunes of Presidio. It also occurs in remnant dune scrub at Sunset Heights (Hawk Hill, 14th Avenue near Riviera Street). The nearest coastal populations are in Monterey County; the nearest interior populations are at the Antioch Dunes, Contra Costa County (Munz 1959). San Francisco is the type locality.

10. Franciscan Leafy-daisy, *Erigeron foliosus* Nutt. var. *franciscensis* G. Nesom

Franciscan leafy-daisy is a perennial herb in the aster family (Asteraceae) that grows from a low woody base, with daisy-like flowers and narrow linear leaves. It occurs in sandy grasslands or openings in coastal scrub of stable dunes, bluffs, or woodlands. Regionally, the species was uncommonly collected in San Mateo and Marin Counties (Howell 1949, Thomas 1961), but these floras assigned the local taxa to var. *hartwegii*. *Erigeron foliosus* var. *hartwegii*, as currently interpreted, occurs only in the north and central Sierra, while all *Erigeron foliosus* in the San Francisco Bay area is referred to variety *franciscensis* (Nesom 1993). In San Francisco, leafy-daisy occurred historically at Point Lobos and Lake Merced (Howell *et al*. 1958), both likely coastal dune scrub habitats. Its current status in San Francisco is not known, but it has not been recently reported, and may be locally extirpated.

11. Yarrow-leaf Gilia, *Gilia millefoliata* Fischer and C. Meyer

Yarrow-leaf gilia (*Gilia millefoliata*) is an annual herb in the phlox family (Polemoniaceae) with a skunk-like scent, finely dissected leaves, and sparse clusters (not dense heads) of purplish flowers. It occurs generally on stable coastal dunes, becoming relatively frequent on north coast dunes from Mendocino to southern Oregon (Smith and Wheeler 1990-1991, Day 1993). The taxonomic affinity of the *Gilia millefoliata* of San Francisco is questionable. All San Francisco collections were made in rocky grassland habitats remote from coastal dunes, often in serpentine (Howell *et al.* 1958). Thomas (1961) and Howell *et al*. (1958), placed the San Francisco collections within the more widespread *Gilia clivorum* (Jepson) V. Grant, a species common in grassy vegetation of rocky soils, but these specimens were interpreted as *Gilia millefoliata* in San Francisco by Day in the Jepson manual (Hickman 1993), despite the anomalous soil type and habitat for *Gilia millefoliata*, but typical habitat for *Gilia clivorum*. (Day's key distinguishes these two taxa based on continuous variation in calyx length; Munz's [1959] key distinguishes them using qualitative characters, but excludes *Gilia millefoliata* from south of San Francisco, and attributes it solely to dunes.) The San Francisco populations are apparently extirpated. Yarrow-leaf gilia may likely have occurred in San Francisco dunes as well,but Howell (1949) stated that it occurred no farther south than Point Reyes. Classification of the extirpated San Francisco plants should be verified from herbarium specimens, since the historic rocky habitats of San Francisco collections are most congruent with the common and variable *Gilia clivorum* of the coast ranges.

12. San Francisco (Chamisso's) Dune Gilia, *Gilia capitata* Sims ssp. *chamissonis* (E. Greene) V. Grant

San Francisco dune gilia (colloquially "dune gilia") is another skunky-scented annual herb in the phlox family (Polemoniaceae) (Day 1993) (Figure 9). It is restricted mostly to vegetation gaps in low-growing coastal dune scrub and stable dune grassland. Dune gilia has showy clusters of lavender-blue to deep violet flowers borne on long stalks, and has finely dissected linear leaves, which are sometimes fleshy. It occurs infrequently but in local abundance in sparse coastal dune scrub and grassland vegetation from Sonoma County (Best *et al*. 1996) to San Mateo County (including Hillside Park, Daly City, on inland sands with San Francisco lessingia) (Howell 1949, Howell *et al*. 1958, Thomas 1961, McClintock *et al*. 1990). In San Francisco it occurs in most large dune remnants, and also on sandy soils of Yerba Buena Island (M. Wood, pers. comm. 1999). San Francisco forms appear to be distinctly taller, and have less intense purple pigmentation than forms from the largest of the subspecies' populations at Point Reyes dunes (P. Baye, pers. observ.). The type locality of *Gilia achilleifolia* ssp. *chamissonis* (Greene) Brand and other synonyms of this subspecies (but not of the species *Gilia capitata*, in which this taxon is now placed) is San Francisco.

13. Wedge-leaf Horkelia, *Horkelia cuneata* Lindley ssp. *cuneata*

Like the related Kellogg's horkelia (*H. cuneata* var. *sericea*), wedge-leaf horkelia is an herbaceous perennial member of the rose family (Rosaceae). In dune systems, wedge-leaf horkelia is generally restricted to older dune soils (P. Baye, pers. observ.). It is more widespread and common in sandy coastal soils than Kellogg's horkelia (Thomas 1961, Ertter 1993), but it has apparently become extirpated in San Francisco dunes, and is rare on coastal dunes north of Monterey Bay (P. Baye, pers. observ. 1990's). Wedge-leaf horkelia typically grows on old dunes and sandy soils in coastal grassland or scrub vegetation along the central and southern California coast (Munz 1959).

14. Common Linanthus, *Linanthus parviflorus* (Bentham) E. Greene

Common linanthus is a relatively more common showy annual herb in the phlox family (Polemoniaceae), compared with its relative, *Linanthus grandiflorus* (Patterson 1993) (Figure 9). It is widespread in grasslands, sandy soils, and partly shaded rocky slopes in the San Francisco Bay area and the north coast ranges. The nearest coastal dune populations are known from Point Reyes, where it occurs in old dune soils with the endangered Sonoma spineflower (*Chorizanthe valida*) and the rare Marin horkelia (*Horkelia marinensis*) (P. Baye unpublished data 1999). It was formerly collected in colonies at the Presidio and Lake Merced (probable dune localities) from the late 19th century to the middle 20th century (Howell *et al*. 1958), and was widespread in stable dunes of the western part of the City in the late 19th century (Brandegee 1892). It has been locally extirpated in remnant dunes of San Francisco. It was reported in the San Francisco flora (Howell *et al*. 1958) as *Linanthus androsaceus* (Benth.) E. Greene var. *croceus* (Milliken) H. Mason, a taxon now placed in synonymy with *Linanthus androsaceus* (Patterson 1993) as common on coastal bluffs and grassy slopes of the northern San Mateo coast (Thomas 1961).

15. Skunkweed, *Navarretia squarrosa* (Eschscholtz) Hook. and Arn.

Skunkweed is a common and widespread annual member of the phlox family (Polemoniaceae), easily recognized by its resinous foliage and spiny flower-heads with strong skunky glandular scent. Skunkweed is generally common in sandy alluvium, roadsides, dried winter pools, and general disturbed annual habitats. It was formerly found in dunes and sandy soils of the Sunset, Lake Merced, and the Presidio (Howell *et al.* 1958, Wood 1996), but locally has become rare in San Francisco's remnant dunes and sandy soils of the Presidio (one site off Battery Caulfied Road). The Presidio of San Francisco was the type locality (Howell *et al.* 1958).

16. California Broomrape, *Orobanche californica* Cham. and Schldl. ssp. *californica*

California broomrape is a parasitic, leafless, nongreen plant in the broomrape family (Orobanchaceae) is generally uncommon (Heckard 1993). Clustered broomrape, *Orobanche fasciculata* Nutt., a widespread species, is local and uncommon as well; neither has been reported or collected from San Francisco in recent years. California broomrape appears occasionally in dunes from Goat Rock (Russian River mouth, Sonoma County) to Morro Bay dunes (San Luis Obispo County), and it also occurs in coastal bluff grassland (P. Baye unpublished data 1990's). California broomrape was collected from San Francisco sand dunes (locality unspecified) early in the 20th century (Howell *et al*. 1958). Clustered broomrape has been collected from serpentine vegetation on the Presidio and Laurel Hill Cemetery, historic localities of Raven's manzanita. Little is known about the propagation or reintroduction of these obligate parasitic plants. San Francisco is the type locality of California broomrape.

17. Coast Rein-orchid or Coast Piperia, *Piperia elegans* (Lindley) Rydb.

Coast rein-orchid is a terrestrial orchid that grows leaves in spring, dies back in early summer, and produces a nongreen spike of white flowers in late summer and fall (Figure 9). It is uncommon and local on sandy coastal bluff grassland and scrub in the Presidio, and under eucalyptus groves in remnant dunes near sea level behind Baker Beach (Golden Gate National Recreation Area unpublished data 1998). It is also historically uncommon in coastal scrub of the San Mateo coast (Thomas 1961) and rare on the Marin coast (Howell 1949). It was formerly common in the dune-dominated western parts of San Francisco earlier this century (Howell *et al*. 1958). San Francisco was the type locality of the synonym *Habenaria greenei* Jepson.

IV. RECOVERY

A. Objectives and Criteria

The overall objectives of this recovery plan are to improve the population and habitat status of the species sufficiently to warrant delisting of San Francisco lessingia and reclassification of Raven's manzanita to threatened status, and to prevent the species of concern from becoming threatened or endangered. (Recovery of Raven's manzanita sufficient to warrant delisting is not projected for the foreseeable future.) Instrumental to these objectives are the protection and stabilization of existing populations, and the expansion of restored natural communities with augmented and newly established populations of listed species and species of concern. This plan's recommendations are based on current understanding of the biology of the species. Recovery criteria and strategies may be adapted to accommodate improved understanding and additional information. Future modifications of recovery actions and criteria will be informed by research results and management experience that follow from implementation of recovery actions.

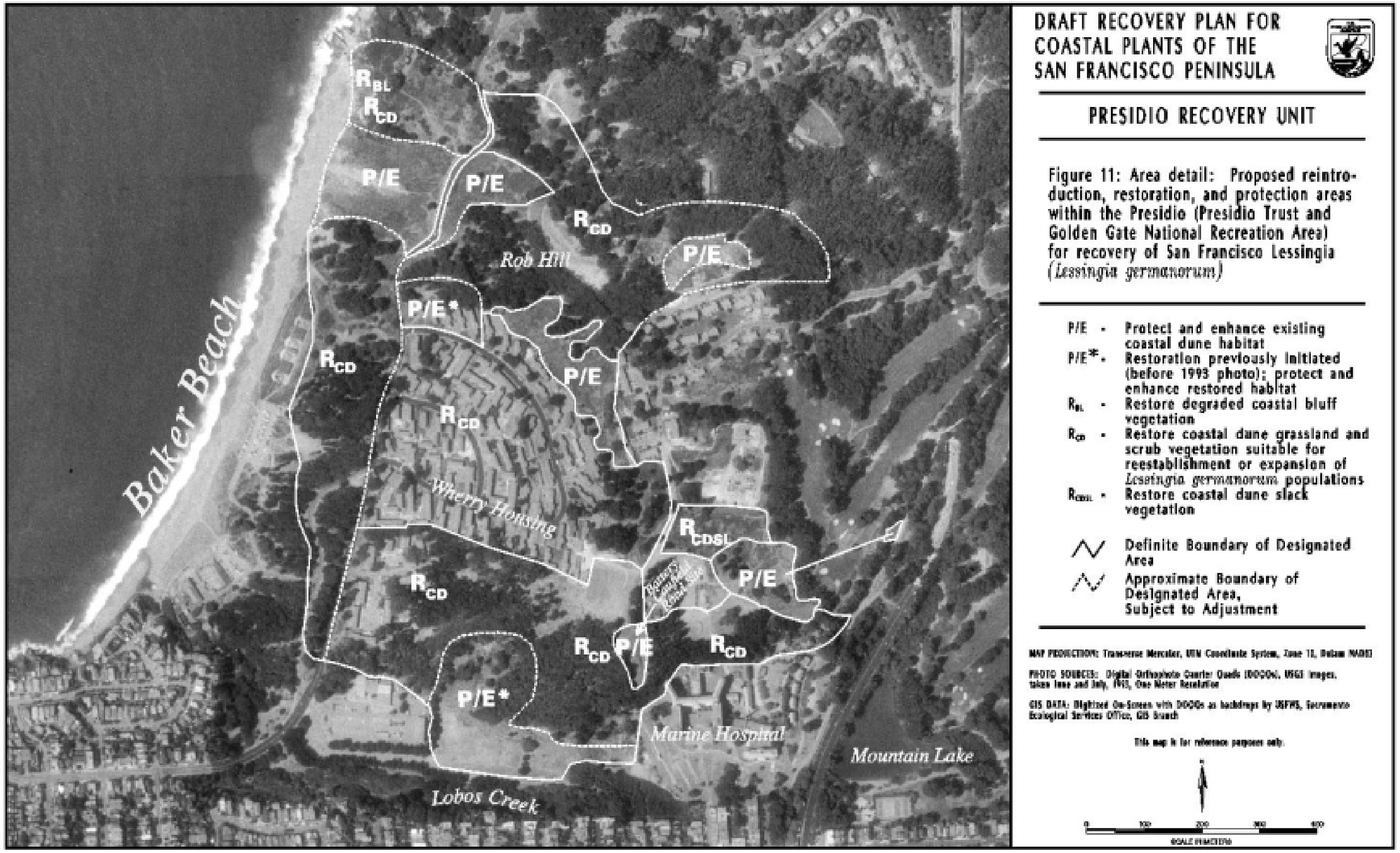
1. Recovery Criteria for San Francisco Lessingia

Recovery criteria for San Francisco lessingia apply to existing populations (interim criteria), to future expanded populations in restored habitats within recovery units, and to the ecological processes and conditions of the plant communities in which they occur. San Francisco lessingia may be considered for reclassification to threatened status when all interim recovery criteria are fully achieved, <u>and</u>: (a) the Fort Funston (Lake Merced area) reintroduction of San Francisco lessingia has been completed and has persisted over at least one precipitation cycle (intervals of above-average and below-average rainfall years), and (b) expansion of the Lobos Dunes unit to at least Battery Caulfield Road and upper Baker Beach has been achieved. The species may be considered for delisting when all long-term recovery criteria have been met, which could occur no sooner than 20 years after initiation of implementation.

a. Interim Recovery Criteria. Interim recovery criteria apply to existing populations in relict and restored habitats. They are aimed at ensuring that these populations do not undergo significant long-term declines in size, number of subpopulations, areal extent, or population variability while long-term recovery measures are in preparation. These criteria are primarily aimed at specific areas occupied by San Francisco lessingia, and the dynamic quality of the vegetation in these areas. The dynamic quality of vegetation partly determines the suitability of an area for the regeneration of San Francisco lessingia. Progressive trends toward dense, closed woody or perennial vegetation with few open gaps dominated by annuals would indicate a loss of suitable local conditions for San Francisco lessingia (see discussion in Chapter II under Ecology and Reproduction). In contrast, a patchy dune scrub and grassland vegetation including gaps, sparse vegetation patches, erosional areas, and extensive low herbaceous vegetation in varying successional stages indicate favorable conditions for colonization or persistence by San Francisco lessingia. Population sizes discussed here refer to the number (census or estimated population size) of mature, spontaneously established seed-producing individuals of San Francisco lessingia, but *not* directly sown or transplanted individuals, seedlings, or pre-reproductive plants.

Interim population criteria for this annual species are not based on management for or maintenance of a fixed population size over time. The population criteria anticipate large natural fluctuations over precipitation cycles. Precipitation cycles vary in length, but are expected to be 5 to 10 years in duration. Prescribed population sizes are expressed as minimum lower thresholds and expected upper targets. They do not represent averages over multiple years. The interim recovery criteria for San Francisco lessingia apply to the period before major, large-scale habitat restoration begins. Large-scale restoration here refers to widespread tree removal, control of nonnative vegetation, reintroduction/regeneration of native dune vegetation, and linking currently isolated lessingia reserves. A general interim recovery criterion for all sites is that each must be secured under long-term protection and management favoring persistence (as described in the narrative outline). These recovery criteria primarily address listing criteria 1 (present or threatened destruction, modification, or curtailment of its habitat or range) and 4 (the inadequacy of existing regulatory mechanisms), and secondarily address listing criterion 5 (other natural or manmade factors affecting its continued existence).

Figure 10: PRESIDIO RECOVERY UNIT for San Francisco Lessingia (*Lessingia germanorum*) Delineation of the recovery unit boundary within the Presidio


DRAFT RECOVERY PLAN FOR
COASTAL PLANTS OF THE
SAN FRANCISCO PENINSULA
PRESIDIO RECOVERY UNIT
Figure 11: Area detail: Proposed reintroduction, restoration, and protection areas within the Presidio (Presidio Trust and Golden Gate National Recreation Area) for recovery of San Francisco Lessingia (*Lessingia germanorum*)
P/E - Protect and enhance existing coastal dune habitat
P/E* - Restoration previously initiated (before 1993 photo); protect and enhance restored habitat
R_{BL} - Restore degraded coastal bluff vegetation
R_{CD} - Restore coastal dune grassland and scrub vegetation suitable for reestablishment or expansion of *Lessingia germanorum* populations
R_{CDSL} - Restore coastal dune slack vegetation
Definite Boundary of Designated Area
Approximate Boundary of Designated Area, Subject to Adjustment
Baker Beach
Rob Hill
Wherry Housing
Marine Hospital
Mountain Lake
Lobos Creek
P/E
P/E*
R_{BL}
R_{CD}
R_{CDSL}

i. Presidio Recovery Unit (Figures 10 and 11)

(1) *Lobos Dunes Reserve*. The restored Lobos Dunes site is now effectively the core population for the species (Figure 11). Acceptable population size for San Francisco lessingia here may fluctuate between 50,000 and more than 500,000 plants within a precipitation cycle. It would not be acceptable to stabilize the population at or near 50,000 in a small portion of the site: it is essential that lessingia numbers fluctuate, with occasional years of high numbers, and that the species be distributed over most of the site. At this core population, no significant net long-term decline in population size (e.g., decline between successive precipitation cycles) should occur relative to target numbers. "Fluctuation" does not include changes in population size caused by progressive changes in vegetation composition and structure that would occur over decadal time scales (e.g., shifts in dominance to closed-canopy shrub vegetation).

In addition, interim recovery criteria for Lobos Dunes require that nonnative vegetation (primarily annual grasses, but also iceplants, *Conyza*, and Bermuda-sorrel) be reduced to less than 5 percent maximum cumulative annual cover (the peak cover percentage of all invasive species, with different seasons for peak abundance of various species), with progressive incremental decreases annually. While it is a goal to locally eradicate these invasive nonnative plants, it is a necessity to at least reduce them to minimal levels. The percentage of sand surface with bare/sparse dune surface (bare to sparsely vegetated *or* dominated only by native annuals) must be at least 20 percent cover at relatively large spatial scales (patch sizes greater than 3 meters [3 yards]) over the entire Lobos Dune site. Substrate conditions within 30 centimeters (12 inches) surface depth must match old dune sand (closely similar texture, nutrient, and moisture holding capacity) and be conducive to regeneration of target dune vegetation. Reference conditions for substrate conditions may be based on relict population sites (e.g., Presidio Golf Course roadside, Rob Hill, behind Marine Hospital) where dune soils are not amended with imported fill or augmented organic matter from nonnative vegetation. Nondune sand substrate that facilitates weed invasion or accelerated succession to mature coastal scrub must be minimized to less than 5 percent of the managed dune surface area of the Lobos dunes site.

(2) *Battery Caulfield Roadside Reserve.* This population (Figure 11) should not decline below 1,000 plants in any 3 consecutive years. Population size should intermittently reach or exceed 5,000. At this smaller, sheltered, partly shaded site, nonnative vegetation (primarily annual grasses, but also iceplants) must be reduced to less than 20 percent peak annual cover, with progressive incremental decreases annually. Local extirpation of these invasive nonnative plants is a goal, but reduction to minimal levels is necessary. The percentage of sand surface with bare/sparse dune surface (bare to sparsely vegetated or dominated only by native annuals) must be at least 10 percent cover.

(3) *Wherry Dunes Reserve*. The current size of this site is approximately 4 hectares (10 acres); it is expected to be enlarged (Figure 11). The population should not decline below 5,000 plants in any 3 consecutive years. General vegetation criteria for Lobos dunes apply here.

(4) *Rob Hill Reserve*. The population should not decline below 5,000 in any 3 consecutive years, with intermittent years reaching or exceeding 50,000 over a precipitation cycle (Figure 11). Vegetation criteria for the Battery Caulfield site apply here.

(5) *Marine Hospital ("Presidio Hills") Reserve*. This reserve includes the Presidio Golf Course roadside site (Figure 11). The combined population size of the Marine Hospital site and Golf Course site should not decline below 5,000 plants in any 3 consecutive years. Neither population alone may decline below 1,000 plants in any year. Vegetation criteria for the Battery Caulfield site apply here.

ii. Southern Recovery Unit and Offsite

(1) *Daly City Reserve*. The population here should exhibit no net long-term (progressive trend exceeding 3 years) decreases in spatial distribution or the order of magnitude of population size within this site (Figure 6). The

population should not decline below approximately 50,000 plants over any 3 consecutive years. Intermittent peak year population sizes should exceed approximately 200,000. The abundance (density and cover) and distribution of nonnative vegetation (particularly iceplant and ripgut bromegrass) should exhibit no progressive (more than 2 consecutive years) increases within any portion of the site that is persistently or intermittently occupied by San Francisco lessingia.

(2) *Offsite*. Long-term seed storage will ensure that founder populations from each site could be reestablished in the event of local extinction. Seed samples totaling at least 500 seed from separate parents (not clusters of siblings in seedheads) sampled randomly throughout each site in its entirety should be collected annually. Each annual collection should be placed in dry, above-freezing refrigerated conditions at either the Golden Gate National Recreation Area native plant nursery or local botanical gardens equipped for long-term seed storage. Seed should also be deposited at a botanical garden approved by the Center for Plant Conservation.

b. Long-term Recovery Criteria. All long term recovery criteria presume that the interim recovery criteria are completely met. Long term criteria apply to the three recovery units: The Presidio Recovery Unit should consist of dune complexes around nuclei of preserved sites, many of which should eventually be connected and integrated in larger reserves. The Southern Recovery Unit should consist of Daly City and Fort Funston reserves. The Fort Funston Reserve should consist entirely of restored dunes with reintroduced populations of San Francisco lessingia from Daly City. The Daly City Reserve should consist of a small area of managed vegetation including the preserved population there, surrounded by native buffer vegetation zones in the same parkside and residential setting. The Satellite Recovery Unit should consist of smaller reserves with San Francisco lessingia populations relatively isolated from the main reserves in the Presidio, Fort Funston, and Daly City. These reserves should be located on small open space areas in San Francisco containing restorable dune remnants at Sutro Heights and Sunset Heights. These recovery criteria primarily address listing criteria 1 (present or threatened destruction, modification, or curtailment of its habitat or range), and secondarily address listing criterion 5 (other natural or manmade factors affecting its continued existence).

The proposed Recovery Units must be permanently protected as natural area reserves with vegetation management priorities and objectives dedicated to the persistence of the San Francisco lessingia populations within the restored native dune vegetation and dynamics that sustain them. The dedicated areas within lands of Golden Gate National Recreation Area, Presidio Trust, and the City of San Francisco must be permanently established, unaffected by potential land ownership transfers or proposed changes in land use. Other park uses which are potentially compatible with the persistence of San Francisco lessingia populations, such as well-regulated public access, may be retained or modified to ensure compatibility. Incompatible park uses (planted trees or dense shrub cover, road construction, irrigation, fertilizer application, construction of buildings, etc.) must be excluded from Recovery Units in perpetuity.

i. Presidio Recovery Unit. Long-term recovery criteria apply principally to future populations of San Francisco lessingia that have expanded into integrated, consolidated reserves of restored dune areas around core remnant populations, or around large founder populations derived from them. The long-term criteria, like the interim criteria, are focused on specific geographic areas and their habitat qualities. For long-term recovery, vegetation dynamics involving partial dune instability (local blowouts with cycles of erosion, deposition, and stabilization) are an essential qualitative criterion for the Lobos-Wherry-Baker and Fort Funston reserves. The sizes and local distributions of San Francisco lessingia populations in these reserves are expected to fluctuate substantially between years. The criteria do not allow for artificially maintained large populations, as could be achieved in the short term by intensive habitat manipulation (e.g., intensive manual weeding, re-seeding, artificial maintenance of early successional stages of dune scrub). Instead, the criteria follow an ecosystem management approach: they are based on natural fluctuations of population size over large, heterogeneous areas of mature, high quality habitat. Numeric population criteria are therefore only approximate, and magnitude of population sizes relative to annual fluctuations is more pertinent than short-term census data.

The aim of long-term criteria is to ensure that resilient, dynamic landscape units continue to support mobile populations of San Francisco lessingia that are well-distributed in reserves that faithfully represent the native ecosystem of the species. Failure of long-term recovery criteria would be indicated by progressive declines of San Francisco lessingia populations, by progressive deterioration of vegetation (excessive total vegetation cover and dune stability, progressive increases in cover of invasive nonnative vegetation), impoverishment of native species diversity within the reserves, or establishment of fragmented or undersized reserves. Excessive or insufficient vegetation management, such that natural vegetation and population processes are overriden, would also indicate failure of recovery criteria. Over-management would be indicated by need for periodic "restocking" (augmentation) of San Francisco lessingia populations by supplemental seeding, or periodic replanting of native vegetation in previously restored dune areas.

(1) *Lobos-Wherry-Baker Dune Reserve*. This section of the Presidio Recovery Unit would incorporate and coalesce areas at Baker Beach dunes, Lobos Dunes, Wherry Dunes and Housing sites, conifer groves around Lobos Dunes, and the Battery Caulfield Road site (Figure 11). Criteria for this complex are designed to ensure unobstructed wind fetch from the Golden Gate, through Baker Beach and its restored climbing dunes. The combination of large open fetch, high and steep slopes and extensive dune area (approximately 44 hectares [110 acres]) here must sustain dune dynamics favorable for patchy, variable dune vegetation and persistence of San Francisco lessingia, minimizing the need for intervention to maintain specific phases of dune succession. This complex must be large enough to enable turnover (dynamic local extinction and colonization) of San Francisco lessingia patches, and minimize the likelihood of population extinction. The reserve design need not preclude other park uses and management of the reserve that are compatible with these criteria.

(a) *Structural habitat criteria*. This complex must be restored to be a contiguous dune field. It must consist of a matrix of coastal dune scrub and grassland, with a mosaic of active and stabilizing dune blowouts at varying stages of local succession (erosion, deposition, and stabilization phases). The dune complex must have: (1) effectively unobstructed wind fetch to the Golden Gate, and (2) locally steep dune slopes to ensure minimum persistent small-scale erosion and sparse vegetation peripheral to blowouts and within stabilizing blowouts. Progressive succession to stable, closed dune scrub or grassland vegetation would conflict with this criterion. Large-scale, intensive dune mobility (accretion/erosion greater than 25 centimeters [10 inches] per year in areas exceeding 0.2 hectare [0.5 acre] may not occur over more than 15 percent of the complex in any year. The portion of the reserve area with cover of either bare sand (exclusive of primary pedestrian trails) or sparsely-vegetated sand dominated by annuals and short-lived perennials should be a minimum of 5 percent. These criteria should be achieved incrementally in phases (involving demolition of buildings and removal of nonnative tree plantings), at or near completion within 20 years.

(b) *Population and vegetation criteria*. Nonnative vegetation cover must not exceed 5 percent (annual peak cover) during the first 10 years of dune restoration, and must exhibit a declining trend during the first 15 years. Population size of San Francisco lessingia within this complex may exhibit extreme fluctuations locally (including local extinction of colonies), but population size should not fall below approximately 500,000 in any 3 consecutive years, and should be distributed patchily (not continuously) over most or all of the complex. No maximum population size is set as a criterion, but peak population size should intermittently exceed one to several million plants. Large population size *per se* is not a preeminent criterion for long-term recovery. Extremely high population sizes may be expected in early successional phases of dune restoration sites, but are not likely to be maintained when woody species achieve stable dominance patterns. Multiple new colonies (variable size patches of relatively high San Francisco lessingia density) must become established spontaneously (without artificial dispersal or supplemental seeding) in the complex within 10 years. Population peaks of several million plants should occur within 10 years. Criteria should be met in this reserve about 10 years (and no later than 20 years) after basic restoration work (tree removal, structural demolition, regrading) has been completed in the reserve.

(2) *Rob Hill Reserve* (expanded; Figure 11)

(a) *Structural habitat criteria*. The area supporting native dune vegetation compatible with colonization and regeneration of San Francisco lessingia must be increased to approximately 2 hectares (5 acres) by removing peripheral nonnative trees and groundcover vegetation (eucalyptus, iceplant, ivy, acacia). In addition, the southwest slope of Rob Hill facing the expanded Wherry Dune Reserve must be restored to relatively sparse, low dune scrub vegetation to increase connectivity between these populations (low but biologically significant immigration of San Francisco lessingia from the Lobos-Wherry-Baker Reserve) (Figure 11).

(b) *Population and vegetation criteria*. Population size should not fall below approximately 100,000 (following expansion of habitat) at this site for any 3 consecutive years, and San Francisco lessingia should be distributed over most of the site. Population size should significantly exceed this threshold in intermittent years, but no numeric peak targets are specified. Peak population size would be expected to exceed one million plants, particularly early in succession following dune restoration. Nonnative vegetation (primarily annual grasses at this location) must be reduced to less than 5 percent peak seasonal cover, with progressive incremental decreases annually, aimed at local extirpation. Iceplant recolonization must be prevented by recurrent removal of seedlings. If population size criteria are not met, management must include periodic localized mechanical disturbance of vegetation cover to expose patches of bare or sparsely vegetated dune sand on approximately 2 to 5 percent, and up to 15 percent, of the restored dune area at least once every 7 years, or more often. Vegetation trends over a period of 20 years must exhibit long-term persistence of large areas dominated by annual native vegetation or sparse cover of mixed native annuals, perennials, and shrubs, over at least 25 percent of the site.

(3) *Marine Hospital Site* (expanded; Figure 11)

(a) *Structural habitat criteria*. The dune slope behind the Marine Hospital above a 15-meter (50-foot) wide area extending from the base of the slope zone must have all nonnative trees and shrubs and their debris removed from the slope, so that the upper slope can be restored and exposed to southwest wind influence (Figure 11) . The base of the slope within the 15-meter (50-foot) wide zone may be retained for ornamental landscape plantings that do not exceed approximately 6 meters (20 feet) in height. The area of restored dune area occupied by patches of San Francisco lessingia must be at least 3 hectares (7 acres). Nonnative trees and shrubs around the local oak woodland dune remnant must be removed, but the remnant native dune vegetation should not be subjected to any earthwork. Topographic relief of regraded slopes must be irregular, including steep local slopes with variable aspects. Management must include periodic mechanical disturbance of restored (not remnant woody) vegetation cover to expose patches of bare or sparsely vegetated dune sand on approximately 2 to 5 percent (but up to 15 percent) of the restored dune area at least every 7 years, or more often if population criteria are not met.

(b) *Population and vegetation criteria*. The local San Francisco lessingia subpopulation must colonize the cleared slope behind the former Marine Hospital. Population size in the remnant and restored areas should intermittently reach or exceed approximately 300,000 within 10 years, and should not fall below approximately 50,000 in any 3 consecutive years. In addition, nonnative herbaceous vegetation (primarily annual grasses) should be reduced to less than 5 percent peak seasonal cover, with progressive incremental decreases annually, aimed at local extirpation. Woody nonnative vegetation must be prevented from regenerating after removal. Vegetation trends over a period of 20 years must exhibit long-term persistence of large areas dominated by annual native vegetation or sparse cover of mixed native annuals, perennials, and shrubs, over at least 25 percent of the site.

ii. Southern Recovery Unit

(1) *Daly City Reserve* (expanded)

(a) *Structural habitat criteria*. Because this site is not part of a dune system, and was artificially created by grading activities, structural criteria do not apply. Vegetation management by humans, rather than reestablishment of natural dune ecosystem processes, will be applied in this reserve.

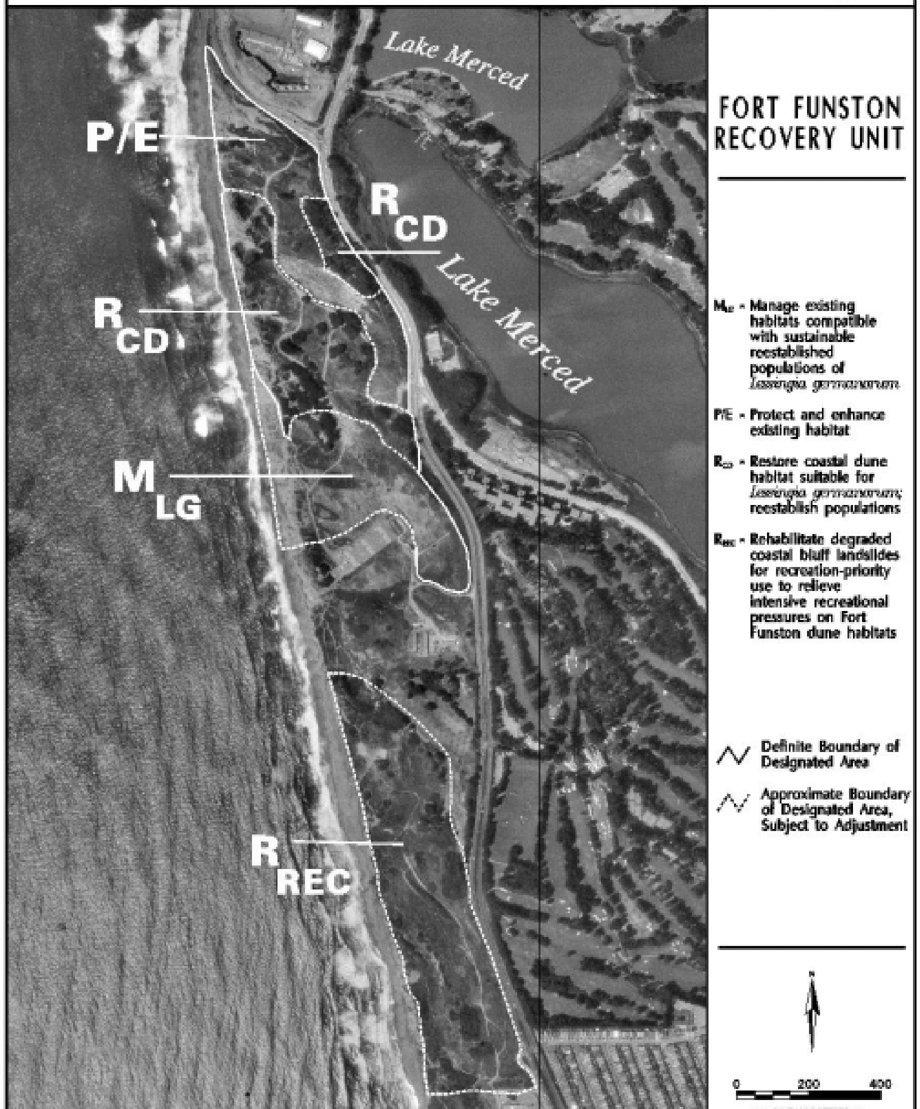
(b) *Population and vegetation criteria*. At least 1.2 hectares (3 acres) of this site must be (gradually) cleared of nonnative vegetation, to establish a minimum core population of at least 50,000 plants under actively managed conditions (Figure 6). The overall population should exhibit no net long-term (progressive trend exceeding 3 years) decreases in spatial distribution or order of magnitude of population size within this site. Minimum population size (combined for the intensively managed core area and areas beyond it) for any 3 consecutive years is approximately 50,000 plants, with intermittent peak years exceeding approximately 200,000 (the same as for the interim criteria). If population size criteria are not met, management should include periodic mechanical disturbance of restored (not remnant woody) vegetation cover to expose patches of bare or sparsely vegetated sand on approximately 2 to 5 percent, and up to 15 percent, of the managed sandy coastal scrub area at least every 7 years. The abundance (density and cover) and distribution of nonnative vegetation (particularly iceplant and ripgut bromegrass) should exhibit no significant increases within any portion of the site that is persistently or intermittently occupied by San Francisco lessingia.

(2) *Fort Funston Reserve* (Lake Merced reintroduction) (Figure 12):

(a) *Structural habitat criteria*. A total of approximately 30 hectares (75 acres) of the reserve, including at least 26 hectares (65 acres) of contiguous restored dune area at the north end of Fort Funston (north end reserve), must be dedicated to dune restoration and vegetation management favorable to San Francisco lessingia (Figure 12). In addition, a 4-hectare (10-acre) area of remnant dunes nearer the southern end of Fort Funston, subject to mixed park use, should be managed as a subsidiary area for a reintroduced San Francisco lessingia population.

The 26-hectare (65 acre) north end reserve must be composed of a matrix of low-growing coastal dune scrub and grassland, with a mosaic of active and stabilizing dune blowouts at varying stages of local succession (erosion,

DRAFT RECOVERY PLAN FOR COASTAL PLANTS
OF THE SAN FRANCISCO PENINSULA



This map is for reference purposes only.

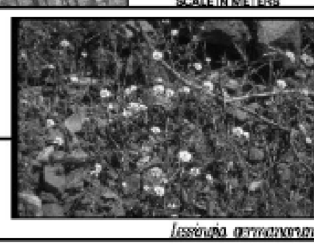
MAP PROJECTION: Transverse Mercator, UTM Coordinate System, Zone 10, Datum NAD83

PHOTO SOURCES: Digital Orthophoto Quarter Quads (DOQQs), USGS Images, taken June and July, 1993, One Meter Resolution

GIS DATA: Digitized On-Screen with DOQQs as backdrops by USFWS, Sacramento Ecological Services Office, GIS Branch

PLANT PHOTO: J.E. (Jed) and Bonnie McClellan, California Academy of Sciences

Figure 12: Southern Recovery Unit for San Francisco *Lessingia germanorum:* Fort Funston proposed reintroduction, restoration and protection areas within Fort Funston (Golden Gate National Recreation Area) dunes, near historic Lake Merced Collection Locality



Lessingia germanorum.

deposition, and stabilization phases). The north end reserve must have unobstructed wind fetch to the sparsely vegetated marine bluff, with no conifer, eucalyptus, or nonnative shrub cover upwind or peripheral to the reserve. Stabilizing iceplant mats must be removed from the reserve, including debris. The dune complex must have locally steep dune slopes to ensure minimum persistent small-scale erosion and sparse vegetation peripheral to blowouts, and within stabilizing blowouts. Progressive succession to stable, closed dune scrub or grassland vegetation would conflict with this criterion. Large-scale, intensive dune mobility (accretion/erosion greater than 25 centimeters [10 inches] per year in areas exceeding 0.2 hectare [0.5 acre]) must not occur over more than 15 percent of the north end reserve. Percentage of the reserve area with cover of either bare sand (exclusive of primary pedestrian trails) or sparsely-vegetated sand dominated by annuals and short-lived perennials should be a minimum of 15 percent. Trampling impacts that cause partial devegetation of dunes, if rotated among areas to alternate between years of disturbance and years of protected revegetation, may be compatible with this criterion at this locality. This criterion should be achieved incrementally in phases within 10 years.

The approximately 4-hectare (10-acre) south end reserve would be less intensively managed or restored for San Francisco lessingia, and criteria would be accordingly more flexible. Vegetation dominated by iceplant, Monterey cypress, or other nonnative vegetation must not exceed 40 percent of the area. Cover of sparse, low, native dune vegetation structurally suitable for San Francisco lessingia must be at least 5 percent. Intensively trampled areas that effectively preclude establishment of San Francisco lessingia seedlings may not exceed 60 percent of the area.

(b) *Population and vegetation criteria*. The reintroduced Fort Funston population, derived from founders obtained from the Daly City population, must achieve a minimum size of approximately 500,000 plants within 10 years after founders are transplanted. The use of the Daly City seed source presumes that this population is natural and genetically distinct from that of the Presidio. Population size may be expected to reach millions of plants temporarily in early phases of dune succession after restoration, but extremely large population size is not prescribed as a recovery criterion. The population must exhibit no progressive long-term (more than 3 consecutive years) declines, and a minimum annual population size of 10,000 plants the fifth year after reintroduction. Multiple new colonies must spontaneously establish outside sites of introduction (with no additional artificial seeding) within the complex within 10 years after implementation of dune restoration work. The population should at least initially be distributed in discrete or coalescing multiple colonies. Cover by nonnative woody vegetation within the reserve must be below 1 percent at any time. Cover of iceplant and European beachgrass by year 10 must be below 10 percent of the reserve area, and must decline progressively. Iceplant must be effectively eradicated from the reserve by year 20, and its density in adjacent buffer areas must be reduced to less than 10 percent. Native dune scrub and grassland vegetation with ample open, partially and moderately disturbed patches should dominate this reserve area.

iii. Satellite Recovery Unit

The Satellite Recovery Unit consists of reserves at Sunset Heights and the Sutro Heights/Cliff House/Lands End area dune remnants. The specific size, number, and configuration of reserves needs to be determined on the basis of more detailed site-specific information than is currently available. Preliminary criteria for this unit are as follows: cumulative population size among all of the remnant dune sites must reach 100,000 plants within 10 years after founders are introduced, with a minimum cumulative annual population size of 5,000 plants for at least 3 consecutive years. Population size criteria should be revised for the Satellite Recovery Unit when the carrying capacity and management constraints of these small sites are better understood through experience and adaptive management. Criteria for vegetation management at the southern reserve at Fort Funston apply to these sites, but management goals should strive to exceed criteria.

2. Recovery Criteria for Raven's Manzanita

Recovery criteria for Raven's manzanita apply to the single remaining wild plant and the existing transplanted clones in the Presidio (interim criteria), to future expanded populations in restored habitats within recovery units, and to conditions of the plant communities in which they occur. Interim criteria are aimed at ensuring that the species as a whole does not become extinct, and that the one remnant wild clone does not die prematurely from threats. The eventual natural death of the wild clone is not expected in the forseeable future. Interim criteria are also aimed at ensuring that cultivated populations of Raven's manzanita are maintained, and that essential information regarding its reproductive biology and potential for reintroduction is investigated. Long-term recovery criteria for Raven's manzanita are aimed at establishment of multiple new sexually reproducing populations in local serpentine vegetation reserves that approximately reassemble the local serpentine flora associates of Raven's manzanita at interior San Francisco localities. Long-term recovery also aims to ensure survival of the remnant clone by increasing its distribution within unoccupied suitable serpentine habitat in the Presidio. These criteria are also aimed at ensuring that populations are not artificially perpetuated solely by vegetative propagation of one clone. If possible, the species should regenerate appropriate variability in ecological, morphological, and genetic characteristics, similar to that of other narrowly endemic manzanitas. Such variability is presumed to be important for continued adaptation and evolution of Raven's manzanita, as for most sexual species (Stebbins 1950, Ghiselin 1988).

Raven's manzanita may be considered for reclassification to threatened status when all interim recovery criteria are fully achieved, <u>and</u>: (1) at least five spontaneously reproducing variable populations are established in reserves on bedrock outcrops outside the Presidio in San Francisco, at least three of which must be on serpentine outcrops; (2) at least two sexually reproduced generations are established within the Presidio; and (3) at all the sites, population size and individual clone size increase over a period of 30 years. These criteria provide a trigger for a review of Raven's manzanita's eligibility for downlisting from "endangered" to "threatened" status. They represent partial fulfillment of long-term recovery criteria, focusing on indicators of sufficient progress towards the long-term recovery goals to justify reconsideration of the level of protected status needed. Because recovery is constrained by the small area of potential restorable habitat in San Francisco, reclassification to threatened status is not foreseeable in less than 30 years, and may not be feasible. Furthermore, recovery sufficient to warrant full delisting of Raven's manzanita (removal of all legal protection under the Endangered Species Act) is not projected within the foreseeable future and may not be possible. This conclusion may be reconsidered in the remote future if success of long-term recovery exceeds current expectations.

a. Interim Recovery Criteria

i. Habitat and Population Stabilization in the Presidio. The site of the original remnant clone and all daughter clones established in the Presidio must be dedicated to permanent habitat protection, maintained, and protected in perpetuity (principally by removing nonnative vegetation). The original and daughter clones must exhibit significant net growth over a 10-year period. This recovery criterion primarily addresses listing criteria 1 (present or threatened destruction, modification, or curtailment of its habitat or range) and 4 (the inadequacy of existing regulatory mechanisms).

ii. Propagation of Seedling and Clonal Stock. Multiple nursery populations of propagated Raven's manzanita must be established within the Golden Gate National Recreation Area (Presidio or Fort Cronkhite nurseries, or both) and at two or more botanical gardens that are committed to conservation of this species. Nursery populations must consist of both clones and seedling-grown plants. Seedling-grown plants must be derived at least from self-pollinated inbred lines (highest priority), but may include separate experimental breeding lines composed of recurrent backcrosses of selected Tamalpais manzanita (*Arctostaphylos montana*) individuals (and possibly Franciscan or other manzanita taxa) on Raven's manzanita if production of inbred lines is not feasible, and if the strategy is recommended by a scientific review panel of manzanita experts, plant conservation geneticists, and others (see Recovery Strategy). The panel should develop a genetic management plan in cooperation with the U.S. Fish and Wildlife Service before any hybridization. Genetic management of the species should be subject to expert peer review. Artificially bred stock should be maintained in both permanent outdoor collections for unrestricted growth (and future potential propagation stock), and in container-grown collections available for outplanting at restoration sites. The total cultivated population size must be maintained at 50 or more daughter clones (of original Presidio plant) at all times, with a goal of 50 seedling plants (preferably inbred, at least initially) that have at least two clonal replicates each (total 200 plants). This recovery criterion primarily addresses listing criteria 1 (present or threatened destruction, modification, or curtailment of its habitat or range) and 5 (other natural or manmade factors affecting its continued existence).

iii. Establishment of New Daughter Clones on Presidio Serpentine Bluff Sites. At least five additional colonies, each comprising at least five of the daughter clones (with a goal of at least five inbred seedling-grown plants), must be established on relatively stable, exposed serpentine outcrops within or above the Presidio bluffs, in areas where pre-existing vegetation is sparse, particularly on steep slopes. New colonies must exhibit net growth 5 years after transplanting with intensive maintenance, and for an additional 5 years after cessation of intensive maintenance. This recovery criterion primarily addresses listing criterion 1 (present or threatened destruction, modification, or curtailment of its habitat or range).

iv. Investigation of Taxonomic Relationships and Reproduction. Studies must be conducted to clarify the taxonomic relationships between Raven's manzanita and Monterey County *Arctostaphylos hookeri* subspecies *hearstiorum* and *hookeri*, Tamalpais manzanita (*A. montana*), bearberry (*A. uva-ursi*), Franciscan manzanita (*A. franciscana*), and other relevant taxa. The breeding systems of these taxa, including comparisons of fruit set and seed viability resulting from within-species crosses and self-pollination, should also be studied. An especially high priority is to experimentally determine the level of self-compatibility (level of viable seed production resulting from self-pollination) in the one remaining clone of Raven's manzanita. Other topics to investigate include variation in reciprocal hybrids among these species, pollen viability of interspecific (between-species) hybrid plants, and chromosome counts of hybrids. Experimental studies of natural ecological conditions favoring seed production and seedling recruitment should be conducted. Fitness of inbred Raven's manzanita plants (e.g., comparison of characteristics related to growth rate, plant size, and reproductive traits) , and reference populations of Tamalpais manzanita from serpentine sites (or other appropriate reference populations of representative manzanitas) should be studied on serpentine and nonserpentine substrates.

Results of these investigations will make it possible to evaluate the need for an introgressive breeding program to restore sexual reproduction and adaptive variability in the species. If introgressive breeding of Raven's manzanita is justified by scientific evaluation of its reproductive biology and taxonomy (see (b) above), similar studies would probably be needed on backcross breeding lines as well. The need for such research should be addressed in the genetic management plan. This recovery criterion primarily addresses listing criterion 5 (other natural or manmade factors affecting its continued existence).

b. Long-term Recovery Criteria

The long-term recovery criteria below represent the maximum level of recovery that we reasonably expect at present, given the irreversible urban constraints to habitat restoration and population expansion. Fulfillment of these criteria is important as a management goal to minimize the threats to the species as much as possible, but is not considered sufficient to warrant delisting. Delisting may be reconsidered in the distant future if success of long-term recovery significantly exceeds current expectations.

i. Reproduction and Growth in the Presidio Bluff Population. If feasible, at least one generation of spontaneously established inbred (not experimental hybrid backcross) seedlings of Raven's manzanita must grow to reproductive maturity in at least one colony out of five new Presidio bluff subpopulations within 30 years after establishment. Over 50 percent of plants within all five colonies must exhibit progressive and significant net growth over 20 years. This recovery criterion primarily addresses listing criterion 1 (present or threatened destruction, modification, or curtailment of its habitat or range) and secondarily addresses listing criterion 5 (other natural or manmade factors affecting its continued existence).

ii. Establishment and Protection of New Interior Populations. At least five mixed populations (Franciscan and Raven's manzanita) consisting of original clones and cloned seedlings (preferably inbred lines, if they are feasible and found to be suitable for reintroduction to novel reintroduction sites) must be established at separate interior San Francisco serpentine outcrop sites. Over 50 percent of founder plants at each new population must exhibit net growth in size over a 10-year period. At least one generation of spontaneously recruited seedlings of Raven's manzanita must establish within 25 years in at least one interior site. Significant recurrent production of viable seed must be in evidence at all five sites. All reintroduction sites must be permanently protected and monitored, and must be permanently maintained to prevent reinvasion by competing nonnative vegetation, degeneration from recreational misuse, or unforseen threats that require adaptive management. This recovery criterion primarily addresses listing criteria 1 (present or threatened destruction, modification, or curtailment of its habitat or range) and 4 (the inadequacy of existing regulatory mechanisms).

iii. Permanent Reserve Cultivated Populations in Botanical Gardens. Horticultural propagation of Raven's manzanita (also interim recovery criteria) must be dedicated in perpetuity at no fewer than four botanical gardens in California. Multiple independent garden collections in different California coastal regions reduce the chance that region-wide catastrophic events (e.g., virulent new pathogens, extreme rainfall) could cause general loss from cultivation. Propagation and cultivation of Raven's manzanita for other specific educational, scientific, or outreach efforts in support of recovery actions recommended in this plan may be needed on a case-by-case basis for recovery implementation, but such propagation and cultivation are not treated as recovery criteria. This recovery criterion primarily addresses listing criterion 1 (present or threatened destruction, modification, or curtailment of its habitat or range).

B. Comprehensive Strategy of Recovery Actions

1. Recovery Strategy for San Francisco Lessingia

Recovery actions are discussed below in the context of independent geographic units. Recovery actions must be implemented sequentially as described below in order to function properly. For example, reintroduction of endangered species before adequate site preparation is completed (control of invasive nonnative plants, soil contouring, establishment of wind fetch corridors, buffers) is likely to fail or require excessive remedial intervention. Similarly, piecemeal restoration of large sites or patches within larger sites is likely to result in excessive edge effects that diminish the habitat value of restored areas, and impede seed dispersal linkages among sites. These recovery actions address both interim and long-term recovery criteria. They are presented as the conceptual basis for subsequent management and restoration plans.

a. Presidio Recovery Unit

i. General Requirements of the Presidio Recovery Unit. The basic strategy for the Presidio Recovery Unit of San Francisco lessingia is twofold: (1) maintain and improve habitat quality of existing populations by suppressing or eradicating competing nonnative vegetation, and (2) enlarge existing populations and habitat by completing phased, large-scale dune scrub and grassland restoration. Dune restoration here places emphasis on reestablishment of natural vegetation patterns, topography, exposure, and dynamic disturbance regimes that will maintain suitable microenvironments for San Francisco lessingia and associated dune annuals.

The Presidio populations of San Francisco lessingia are on Federal lands managed by the Golden Gate National Recreation Area (National Park Service), and owned by either the Golden Gate National Recreation Area (Lobos Dunes restoration site, now the largest discrete population) or the Presidio Trust (Rob Hill, Golf Course, Marine Hospital sites, Wherry Dunes restoration site at the northwest end of Wherry Housing). The geographic scope of the Presidio Recovery Unit for San Francisco lessingia is limited by the distribution of large blocks of dune sand substrate in areas that are covered by scrub, nonnative trees, or nonhistoric buildings previously programmed for demolition. These blocks of substrate occur mainly in the southwest corner of the Presidio. Developed lands (e.g., permanent buildings, golf course, roads) constrain the potential configuration and area of restored dune. The existing San Francisco lessingia sites are separated from each other by nonnative trees (pine, cypress, eucalyptus groves) and developed areas with roads and buildings. A nonnative tree grove between Lincoln Boulevard and Baker Beach also creates a wind barrier that obstructs the fetch of strong winds from the Golden Gate and Baker Beach, and adversely shelter the native dune vegetation. These sites must be reunited to a contiguous block of dune habitat capable of dynamic internal redistribution of sand and seeds. Surface contours of tree-cleared dunes must be modified to include steep, hummocky slopes prone to small-scale erosion that will sustain local vegetation gaps for San Francisco lessingia to colonize.

The first requirement for recovery of San Francisco lessingia in the Presidio is to control invasive nonnative vegetation, which is most important in short-term and near-term survival of the species. The second requirement, to have large blocks of restored dunes with appropriate slopes, orientation, substrate, mobility and wind-fetch, is essential to long-term recovery of the species. Dune restoration must occur at a spatial scale and setting that will allow for blowout dynamics; otherwise, natural vegetation succession toward dense dune scrub would over time reduce or eliminate open microhabitat for San Francisco lessingia. Dune restoration will require extensive removal of nonnative eucalyptus and conifer groves (e.g., Figure 11). The Lobos-Wherry-Baker lessingia reserve will also require phased demolition of the Wherry Housing area, which was programmed in the Presidio General Management Plan Amendment/Environmental Impact Statement (National Park Service 1994). Restoration of a natural, dynamic regime of ecological disturbances and stress maintained by interactions of wind, slope, and dune sand is essential to maintain conditions that will support San Francisco lessingia and suppress invasive nonnative species. Major visual landscape changes such as tree removal in this highly visited part of the park, adjacent to residential areas, will require substantial public outreach and education for support. Landscape changes and outreach activities must be designed and coordinated in phased, site-specific management and restoration plans.

While substantial progress at control of invasive nonnative plants has been achieved at managed San Francisco lessingia sites of the Presidio, reinvasion pressures remain strong, sustaining the need for intensive manual weeding each year. Currently, volunteer labor through community stewardship programs is the mainstay of weeding. Iceplants and annual grasses, especially brome, have recently been principal weeds of the Presidio sites. Expansion of restored and managed dune vegetation will probably exceed the capacity of volunteer weeding at its foreseeable levels. Because native grasses occupy a small proportion of these lessingia sites (mostly through reintroduction in

1996), weed management should be expanded to include experimental applications of appropriate grass-specific herbicides within and around San Francisco lessingia sites (including adjacent source population areas). The experimental program should continue over at least several years, with the aim to exhaust local seed banks of nonnative invasive grasses. Manual weeding would be more effective after reduction of population density and seed bank size of invasive annual grasses. Increased volunteer participation should be encouraged, but resources for trained park vegetation management technicians should be ensured so that weed management can be performed at critical times of the growing season (especially pre-flowering and during seed set) regardless of volunteer levels. These measures must be coordinated in a nonnative vegetation control plan for all Presidio sites that support San Francisco lessingia.

ii. Site-specific Requirements of the Presidio Recovery Unit. The following recovery requirements are presented as preliminary conceptual restoration and reintroduction plans. Conceptual plans must be adapted to site-specific current conditions. Site-specific plans must incorporate detailed information on soils, topography, schedules, costs, engineering and construction methods and requirements, etc.

(1) *Lobos Dunes Reserve*. The Lobos Dunes restoration site must expand further into what are currently degenerating groves of over-mature Monterey cypress trees extending to Battery Caulfield Road and Lincoln Boulevard (Figure 11). Expansion of this core population area is the highest restoration priority for the species, and should precede significant dune restoration at any other lessingia reserves. Tree removal must include removal of woody debris, most stumps, and duff. Restoration actions should include at least 2 years of substrate preparation and weed eradication prior to final contouring and planting of native species, including San Francisco lessingia. Substrate preparation for restoration at this location should include measures to probe for significant seed banks of native species, and to exhaust invasive nonnative weed seed banks. Surface recontouring following seed bank probes must establish appropriate dune topography, including oversteepened northwest-facing erosion-prone slopes. Exposed, bare dune surfaces will need to be temporarily stabilized with inert materials (such as desiccated, dead

beachgrass) prior to revegetation. A buffer area of more continuous stable dune scrub vegetation may be maintained along Battery Caulfield Road, to limit potential sand movement conflicts with road maintenance. Expansion of the Lobos Dunes restoration site will decrease adverse edge effects (shading, fog drip, wind sheltering, leaf litter and leachate, and weed reinvasion) on the existing Battery Caulfield lessingia site. Expansion of habitat will also reduce the risk that San Francisco lessingia populations will significantly decline due to excessive vegetative cover and over-stabilization of dunes.

(2) *Wherry Dunes and Baker Beach*. The Wherry Housing area above Baker Beach is contiguous with the Lobos Dune site (Figure 11). It has the best potential for restoration of dynamic dune scrub and blowout habitat on the Presidio because of its elevation, aspect (facing northwest winds from the Golden Gate, with potentially unobstructed fetch), steep slopes, and underlying old dune sands. The 4-hectare (10-acre) Wherry Dune Restoration site at the north end of Pershing Drive should be expanded both north (to Washington Boulevard) and south (towards Lobos Dunes) in phases, eventually coalescing with the Lobos Dunes restoration site. This expansion will require phased demolition of buildings and removal of the nonnative pine and eucalyptus stands around Pershing Drive and Washington Boulevard, so that old dune scrub above Baker Beach and remnant dune scrub northeast of Wherry Housing area ("Feral Dunes") become incorporated in the complex.

The proposed Wherry-Lobos Dunes restoration complex would be adversely affected by the strong wind-sheltering effects of the planted conifer and blue gum groves between Lincoln Boulevard and Baker Beach unless these groves are removed. These trees obstruct the wind-fetch from the Golden Gate (Figure 11). The wind-shadow of these tree groves would inhibit wind-shearing of prostrate vegetation and reduce the initiation and development of small dune blowouts in the restored dune area. Wind-shear stress and post-blowout revegetation are the natural process most likely to maintain suitable microhabitats for San Francisco lessingia. Nonnative trees also directly displace suitable habitat for San Francisco lessingia and associated species of concern in the dunes above Baker Beach, southwest of the "sand ladder" (pedestrian walkway) on the steep dune slope at the northeast end of Baker

Beach. Most or all of these trees must be removed to restore the wind fetch that is essential for the long-term viability of the Wherry-Lobos Dunes. The trees must be removed before earthmoving at expanded Wherry Dune area, and subsequent substrate preparation and planting. Removal of these trees will also directly provide suitable habitat for San Francisco lessingia and its associated species of concern.

Essential areas for tree removal in dune restoration include upper dune slopes immediately below Lincoln Boulevard, south of the Baker Beach one-way entrance. Small groves of trees lower in the dune slope, near the Baker Beach picnic areas, would be less likely to affect wind velocity upslope. Similarly, removal of trees at the southwest end of Baker Beach would be unlikely to affect the integrity of restored Lobos-Wherry Dunes. The removal of trees in the lower slopes and flats immediately behind the beach would be beneficial but not essential to recovery. On dune slopes immediately above Baker Beach, which are adjacent to abundant relict native dune vegetation, natural recolonization of native species in tree-cleared dunes should be fostered before plans for transplanting of nursery-grown native vegetation are developed. Temporary dune surface stabilization (such as desiccated, dead beachgrass) would initially be needed to enable native seedlings to establish after tree removal. Buffer plantings of native woody dune scrub species, however, would need to be placed along Lincoln Boulevard to stabilize devegetated dunes.

The Presidio Trust’s strategy for Wherry Housing is to lease housing on an interim basis, followed by demolition of the housing and dune restoration within 30 years. The Presidio Trust’s goal (from the Presidio General Management Plan Amendment) had been to demolish all the housing by 2010 (K. Feyerabend, pers. comm. 1998), but this goal is currently under review and analysis of alternatives (Presidio Trust 2001). This goal is compatible with timely phased restoration and integration of the Lobos and Wherry Dune sites. Retention of the housing would prevent recovery of San Francisco lessingia. Phasing demolition to begin in approximately 5 years in the area outside of Pershing Drive, extending below Pershing drive within 15 years, would enable the Wherry and Lobos Dunes units to become fully integrated within about 20 years (by about 2020, or earlier). In contrast, occupancy of all of the Wherry Housing for a full 30 years would obstruct recovery of San Francisco lessingia within this recovery unit because it would preclude integration (migration, gene flow, colonization of newly available patches) with the core of the unit at Lobos Dunes. Prolonged occupancy of the Wherry housing would also set up land use conflicts for full dune restoration including active blowouts in adjacent dunes, by creating wind-sheltered zones in the lee of housing, and by establishing land uses that would be intolerant of adjacent mobile sand.

The final restoration designs of the Wherry dunes and Baker Beach areas should anticipate and encourage the development of dune blowouts of appropriately limited size and distribution. Blowouts should be monitored for early indications of excessive rates of sand transport or excessive spread of erosional areas because large, highly mobile blowouts would be detrimental for San Francisco lessingia, road maintenance, and recreational uses of the park. Most blowout migration rates should not normally exceed an average of 0.5 meter (1.6 feet) per year for more than 3 consecutive years, depending on location and adjacent vegetation and land management. The dunes at this locality are unlikely to become mobilized on a large scale because dune soils here are mature and weathered, and are rapidly colonized by vegetation unless chronic trampling disturbance becomes intensive. Early intervention can control excessive blowouts by: (1) planting locally appropriate dune vegetation in upwind source areas within blowouts during the rainy season of average to above average rainfall years; or (2) placing coarse organic debris (e.g., desiccated beachgrass straw, partly degraded woody brush) in upwind source areas and downwind crests of blowouts during drought years.

(3) *Rob Hill Dune Remnant*. The Rob Hill segment of the proposed Lobos-Wherry dunes complex (near Battery McKinnon-Stotsenberg) supports an important remnant colony of San Francisco lessingia that should be protected, enhanced, managed, and expanded within the site's constraints. The site currently is probably too small and isolated to rely on self-sustaining natural disturbance dynamics. Removal of nonnative trees at the southwest corner of Rob Hill would improve exposure to drying, erosional winds, and sun, thus improving habitat conditions and reduce reliance on intensive management.

This site, however, should remain under intensive vegetation management at least until vegetation and San Francisco lessingia population trends indicate less need for it. In the interim, before habitat is expanded, manual weeding efforts should be increased under the direction of a seasonal or full-time professional vegetation management technician. Adjacent blue gum trees (*Eucalyptus globulus*) and Canary Islands ivy (*Hedera canariensis*) should be removed around the site's margins. San Francisco lessingia and associated native species should be allowed to invade opened sand habitat where trees and ivy are removed, while nonnative plant invasions should be suppressed in these disturbed sites. The Rob Hill reserve may be used to supply additional founders for new San Francisco lessingia populations in the Wherry-Lobos-Baker dune complex.

(4) *Marine Hospital Dune Remnant*. The sandy flats northeast of the former Marine Hospital (Public Health Service Hospital) near 15th Avenue (Figure 11) support relict dune scrub and a rare example of coast live oak on old dunes, as well as substantial but small colonies of San Francisco lessingia in disturbed sandy areas (former road and borrow pit, and dune scrub restoration sites). These colonies, and the small Presidio Golf Course colony nearby on Park Boulevard, are probably associated with the historic records of San Francisco lessingia near Mountain Lake, and were probably also originally linked to the remnant colonies west of Battery Caulfield Road and Lobos Creek. For this reason, these colonies are important to the conservation of the species, and should be protected, managed, and enlarged by restoration of degraded areas within their vicinity. A large proportion of the flats at the northwest end of the site are affected by high groundwater and seeps that have developed vegetation typical of coastal dune slacks. This area is not San Francisco lessingia habitat and should not be restored as such. It would be highly feasible and appropriate to restore this site as coastal dune slack (dune wetland) to support species of concern and an open northwest wind corridor and buffer area, which should be incorporated in the reserve.

Like the Rob Hill site, much of the Marine Hospital site is not well suited to self-sustaining disturbance dynamics because of its relatively sheltered physical setting. It will probably require a relatively high degree of active vegetation management. The sandy south-facing slope behind the Marine Hospital is covered with a grove of nonnative Monterey pine and Monterey cypress. The upper slope also includes large stands of acacia, iceplant, and tea-tree (*Leptospermum laevigatum*). This grove appears to cause significant local wind-sheltering and shading of the dune scrub, and displaces several acres of potential dune scrub/San Francisco lessingia habitat. The slopes above the San Francisco lessingia colonies are dominated by iceplant. The nonnative tree grove and iceplant understory must be removed to expose underlying sand and restore wind-fetch. If re-use of the former Marine Hospital requires buffering landscaping, woody planted vegetation other than tall tree species (preferably dense dune scrub and coast live oak) should be planted only in the lower slope to stabilize it and provide an esthetic buffer without compromising the exposure of the dune vegetation above. The upper slope should be restored in phases to sparse dune scrub vegetation with San Francisco lessingia. Implementation of dune restoration in phases, and use of temporary inert stabilizing materials prior to revegetation, should prevent excessive erosion following tree removal. Removal of planted trees along the east side of Battery Caulfield Road may reestablish low levels of seed dispersal of San Francisco lessingia from the Lobos Dunes area to the Marine Hospital population, which would benefit the population. It would also be beneficial to translocate seed of San Francisco lessingia from the isolated but adjacent golf course roadside cut to restored sand slopes behind the Marine Hospital because orientation to effective winds and narrow dispersal corridors are unfavorable for dispersal of seed from relict sources to new habitat areas. These population patterns are likely the result of past habitat destruction.

(5) *Presidio Golf Course*. The Presidio Golf Course population of San Francisco lessingia occurs along a road cut in dune sand and is relatively small. It is now managed by the Presidio Trust. This colony may be considered to be an isolated part of the Marine Hospital remnant population. It lacks adjacent restorable habitat as long as the golf course remains in use, which is likely. It has little potential for long-term conservation except with intensive management. The population should be conserved in the interim as a hedge against unforseen catastrophic declines in core reserves, but is not a strategic focus for perpetual maintenance or expansion. Seed from this population

should be incrementally reintroduced to the Marine Hospital colonies. Once the Marine Hospital restoration site has established a persistent population and manageable successional trends in an estimated 10 to 15 years, the Presidio Golf Course population should require no extraordinary protection, maintenance, or expansion beyond what Golden Gate National Recreation Area has done in the past. It should be conserved as long as feasible, however.

(6) *Presidio vegetation management planning*. The Presidio Vegetation Management Plan should be updated, and it should establish appropriate specific long-term vegetation objectives for the dune scrub communities supporting San Francisco lessingia. Large areas of dune scrub should include a significant proportion of vegetation gaps (bare soil) and patches of sparse vegetation dominated by native annual plant species. In the Wherry-Lobos Dune complex, the plan should stress the dynamic succession of dune blowouts in various stages (including bare eroding sand). The vegetation management plan should avoid excessively protecting the area from trampling and erosion because too much protection can sometimes promote vegetation succession to closed perennial vegetation cover, especially in wind-sheltered locations. The plan should include provisions for experimental use of managed pedestrian trampling and rotational trail closures and openings as tools to establish vegetation gaps or blowouts. The plan should prescribe intervention if woody or perennial species become excessively or uniformly dominant over large areas, resulting in high percent vegetation canopy cover with few, small gaps. Conversely, if trampling pressures or dune mobility become locally excessive, affected areas should be (temporarily) closed to public access, allowing annual plants to regenerate.

The Vegetation Management Plan should prohibit regeneration of nonnative trees within restored or managed dune scrub areas dedicated to conservation of San Francisco lessingia. The plan should also require adaptive management approaches to invasive weeds, based on frequent surveys to detect incipient colonies or rapid expansions, eradication of incipient colonies, and confining invasion fronts from core weed populations. Weed control should emphasize (in addition to nonnative trees) iceplants (*Carpobrotus edulis* and hybrids, *Conicosia pugioniformis*), annual bromegrasses (*Bromus* spp.), oats (*Avena* spp.), and, for some localities, Bermuda-sorrel (*Oxalis pes-capreae*).

(7) *Maintenance and monitoring*. All Presidio Dune restoration sites and San Francisco lessingia subpopulations should be monitored annually to determine trends of: (a) vegetation succession; (b) reinvasion by nonnative vegetation; and (c) changes in distribution and abundance of San Francisco lessingia. Monitoring should include relatively fine-scale measurements of percent cover of bare sand, leaf litter, and live vegetation, as well as erosion and accretion around San Francisco lessingia colonies and adjacent unoccupied sites. Monitoring should include periodic low-elevation color infrared aerial photography of the Presidio Recovery Unit to enable accurate vegetation maps to be constructed. Monitoring of restored dune areas within complexes should include some detailed subsampling of San Francisco lessingia population dynamics using demographic methods. Monitoring of San Francisco lessingia should compare its population dynamics within blowouts, at blowout edges, and in higher density dune scrub and grassland vegetation. Intensive population data collection, however, should not be applied indiscriminately for monitoring large reserves when more efficient sampling methods would suffice for management.

At least one full-time vegetation technician qualified to maintain restored dune areas should be retained cooperatively by the Golden Gate National Recreation Area and Presidio Trust to integrate long-term monitoring, management and maintenance activities in the restored dune system supporting San Francisco lessingia. The Presidio Vegetation Management Plan should be updated to adapt to the management needs of this unit. A dedicated management fund for restored areas supporting San Francisco lessingia should be established within the Presidio Trust and Golden Gate National Recreation Area Park budgets to ensure that habitat gains from reintroduction in the Presidio are not subsequently lost during periods of budget reduction.

b. Southern Recovery Unit.

i. Daly City Reserve. The Hillside Park sand slope (Daly City) population occurs partly on land owned by the City of Daly City and partly on privately-owned lots that have remained undeveloped on this steep, erosion-prone sandy slope. Although dense stands of San Francisco lessingia are confined to the vicinity of a pipeline and disturbed areas around foot-trails and open sand, San Francisco lessingia has at least recently (1998) spread over most of the area to the west and east. Habitat suitability for San Francisco lessingia here is probably unstable in the long term, and will require management of vegetation in order for San Francisco lessingia to persist there.

At the Hillside Park sand slope, the current property owners have neither the mandate nor resources to conserve San Francisco lessingia effectively. Therefore, recovery will require either: (1) acquisition and transfer of this site (including restorable habitat and buffer areas) to a conservation agency or qualified organization dedicated to conservation of San Francisco lessingia and its native plant community; or (2) establishment of enforceable agreements (possibly easements) to manage the site cooperatively as a reserve for San Francisco lessingia and associated vegetation, coupled with an endowment for management and maintenance to ensure the resources needed for management. Of the two options, acquisition is preferable because it reduces complexity and uncertainty of management. Acquisition should occur through steps including public outreach to neighboring residents, identification of willing sellers, and identification of potential long-term managers.

The areas adjoining the San Francisco lessingia population at Hillside Park support restorable sandy habitats (under mixed native and nonnative vegetation) and plant associations typical of coastal dune scrub. For example, suitable sparsely vegetated and disturbed sand slopes occur next to a public school at the east end of the hill. These slopes afford potential for population expansion, conservation, public stewardship, and scientific education. These areas should be integrated into a comprehensive preserve with different management units. Management units would include: (a) perimeter buffer zones of dune scrub; (b) core Lessingia population area (a priority area for control of invasive nonnative plants); (c) stable dune restoration sites (currently dominated by nonnatives, subject to future lessingia expansion or reintroduction); and (d) dune scrub preserves.

A management and restoration plan for the Hillside Park site should be developed in cooperation with local government and neighboring residents with interest in public access to the site and its educational values. The aims of the management and restoration plan should include: (1) promoting and maintaining sparse, relatively open dune scrub vegetation favoring annual gap-colonizing species, in particular San Francisco lessingia in areas it currently occupies; (2) restoring open dune vegetation in adjoining areas unoccupied by San Francisco lessingia that are dominated by nonnative vegetation; (3) facilitating dispersal and colonization of San Francisco lessingia in restored areas; (4) establishing managed vegetation buffers to slow reinvasion by invasive nonnative species that degrade San Francisco lessingia habitat; and (5) ensuring that all parts of the management unit are efficiently designed and functionally integrated. Management plans should incorporate recovery criteria for this reserve.

Management and restoration plans for the consolidated Hillside Park dune scrub vegetation preserve must include: (a) provisions for ongoing suppression of invasive vegetation within areas currently occupied by San Francisco lessingia, utilizing manual removal techniques or grass-specific herbicides as appropriate; (b) geotechnical assessment of slope stabilization needs; (c) assessment of existing infrastructure (e.g., buried utility lines) constraints, and provisions for any re-routing or replacement of infrastructure to make it compatible with long-term vegetation management; and (d) gradual, phased removal and eradication of iceplant and annual alien grasses, and planting of buffer vegetation comprising native dune scrub species along the edge of the site to retard seed dispersal of annual grasses back onto managed dune vegetation.

Regulated public access to the Daly City Reserve would enable natural history interpretation and provide educational opportunities. Public access designs and interpretative signs for dune scrub habitats should be modifications of those at the Presidio's Lobos Dunes and Crissy Field dune/salt marsh restoration projects, which were designed by the Golden Gate National Parks Association and the Golden Gate National Recreation Area.

Within restored areas, adaptive management plans should prescribe experiments with seasonal closures and openings of pedestrian access to rotate trampling disturbances in sites dominated by dune annuals. This "managed trampling" should be scheduled in the fall, after seed dispersal is relatively complete, but before germination begins. The site and site manager should be endowed with a maintenance capital fund to ensure that sufficient funds will be generated annually to weed and otherwise manage the site.

ii. Fort Funston Reserve. The Fort Funston Dunes are owned and managed by the Golden Gate National Recreation Area. They represent the only large remnant dune habitat that occurs directly within the historic southern portion of San Francisco lessingia's range. The vegetation here includes remnant dune scrub, restored early succession dune scrub, groves of nonnative vegetation (Monterey cypress and pine, acacias and albizias, and extensive areas dominated by iceplant) and bare sand. The Fort Funston dunes are relatively heavily trampled in many areas, and are a highly popular dog exercise area. At least 40 hectares (100 acres) of existing suitable habitat and restorable habitat for colonization by San Francisco lessingia are estimated to exist at Fort Funston, giving the area the potential for a major population. Because intensity of recreational use tends to diminish with distance from parking areas and paved paths, the northern end of the Funston dunes (approximately 26 hectares [65 acres]) should be given highest restoration priority. Major efforts here should be large scale removal of nonnative invasive vegetation, and reintroduction of San Francisco lessingia and associated species.

Toward the south end of the dunes, less intensive management and restoration effort would be appropriate. The semi-disturbed nature of the southern area and the ruderal (weedy) tendencies of San Francisco lessingia probably make reintroduction of this species compatible with the park's mixed recreational and conservation land uses, so reintroduction should not require significant additional restrictions on existing recreational uses if they do not increase in intensity. To prevent future conflicts between lessingia habitat management and potential increases in intensity of recreational use, additional open space lands should be rehabilitated south of Fort Funston along the undevelopable bluffs. Park land use priority for the rehabilitated slopes should be for recreation. Endangered species habitat should not be a priority south of Fort Funston. This strategy should ease recreational pressure on the Funston Reserve, and minimize land use conflicts in the park. San Francisco lessingia should be reintroduced to the Fort Funston Reserve in phases, using founder colonies in temporary small exclosures (fenced areas designed to keep out people or animals). Areas subject to reintroduction in this area should be at least 4 hectares (10 acres).

The first phase of restoration and reintroduction would include cultivation of lessingia transplants at the Fort Funston nursery, and direct sowing into selected relatively bare sand areas already protected from heavy trampling (e.g., existing dune scrub restoration sites). The founder populations should be derived from the Hillside Park, Daly City population, which is closest geographically, and closest in terms of sand/soil characteristics. Seed should be sampled extensively throughout the Hillside Park parent population to allow for high initial genetic diversity on which subsequent natural selection or genetic drift may act after reintroduction. Transplants should be made during rainy weeks in winter. Founder populations should comprise at least 200 transplants and several thousand direct-sown seed, distributed over areas ranging in size from about 0.05 to 0.1 hectare (0.12 to 0.25 acre). Transplanting should be postponed during winters with low, infrequent rainfall. Growth rates of transplants should be augmented by addition of soil nutrients (particularly nitrates) to containers shortly before transplanting.

The second phase would begin once founder populations are established and expanding spontaneously. It would involve mass removal of extensive iceplant mats (from areas with minimal native vegetation) by either mechanical removal (scrapers) or applications of appropriate herbicide, supplemented with manual removal to minimize regeneration of iceplant. Iceplant-cleared plots approximately 0.4 to 1.2 hectares (1 to 3 acres) in size should be replanted patchily with native dune scrub species propagated from local stock. Founder populations of San Francisco lessingia derived from Phase 1 populations should be similarly established in these areas. Once the native species are established and spreading after about 3 to 5 years (depending on climate-driven variables), restored dune scrub areas with reintroduced San Francisco lessingia may be re-opened for recreational access, either on rotational trails or without trail restrictions, as park managers determine appropriate based on monitoring and preliminary studies. Exclosures should be needed only if managers detect widespread severe trampling-related mortality of San Francisco lessingia. If native scrub species develop dense and relatively continuous cover, or if iceplant or annual grasses reinvade restored plots excessively, they should be removed manually or treated with spot herbicide applications to control regeneration and protect the semi-open nature of the vegetation that is conducive to San Francisco lessingia's persistence.

Vegetation management aims for the Fort Funston Reserve should be based on the area occupied and the total population size of San Francisco lessingia, both of which would fluctuate among years. Initial performance over the first 10 years should aim for at least five colonies, each occupying a variable area, with the overall population ranging from approximately 100,000 to 500,000 or more individuals. The Fort Funston Reserve should be monitored and maintained according to the general prescriptions for the Presidio Unit. A dedicated management fund for restored areas supporting San Francisco lessingia should be established within the Golden Gate National Recreation Area Park budget to ensure that habitat gains from reintroduction at Fort Funston are not subsequently lost.

c. Satellite Recovery Unit. It is possible that catastrophic events (e.g., fire, disease, insect outbreaks, etc.) at the Presidio and Fort Funston could cause extinction of the species. To reduce this risk, a series of smaller separate satellite populations should be introduced to independent reserves on restored remnant dune habitats in Sunset Heights and Sutro Heights (near the Cliff House, sand slopes above Balboa Street and 48th Avenue). These sites contain plant species regularly associated with San Francisco lessingia, as well as large stands dominated by nonnative vegetation. These scattered sites are within the ecological and geographic range of San Francisco lessingia, but are not specific historic collection localities. Reintroduction of San

Francisco lessingia to restored areas at these locations would help compensate for the loss of the Lone Mountain population of San Francisco lessingia (all contain hills of Franciscan bedrock, with climbing dune veneers), and would further spread the risk of extinction among more independent populations.

Portions of the Sutro Heights site (lower slope) are privately owned, but much of the area is owned by the City of San Francisco (Department of Parks and Recreation). The Sutro Heights dune remnant site is near the Presidio population, but is similar in soil characteristics (Colma Formation and dune veneer) to the Merced/Oceanside dunes locality where San Francisco lessingia occurred historically. Establishing a new population here would provide geographic and ecological variation for the species that is not provided in the main recovery units. Conditions at this site are comparable to those at the historic (now extirpated) colony at the west end of Baker Beach. If it becomes well established at the Sutro Heights location, San Francisco lessingia might spread spontaneously to some stabilized portions of the engineered dune ridge along Ocean Beach and the Great Highway. It would not establish in areas of mobile sand. The original relict population of San Francisco lessingia near Lobos Creek occurred near a derelict roadside, and other *Lessingia* species are known to behave as weedy invaders of sandy roadsides (Spence 1964). Any adventive colonies spreading from the reintroduced population along Ocean Beach/Great Highway should be treated as dynamic, transient populations; normal maintenance and recreational activities should not be prohibited in attempts stabilize individual colonies here.

Sunset Heights sites also have some potential for joint reserves for experimentally established populations of Raven's manzanita where Franciscan bedrock outcrops (including greenstone) occur. The Sunset Heights dune remnants occur at Grandview Park, a west-facing slope of Sunset Heights Park, an area of mixed outcrops and dunes above 15th Avenue and Ortega Street, and "Hawk Hill." Of these sites, only the "Hawk Hill" site, near 14th Avenue and Santiago Street, above the Herbert Hoover Jr. High School, has been acquired by the City of San Francisco. Hawk Hill also supports many dune plant species of concern and regional conservation significance.

Recovery tasks for Sutro Heights dunes include removal of nonnative woody vegetation (acacia, albizia [plume acacia], Monterey cypress) and iceplant, and stabilization with native dune grassland species. Interim physical stabilization, long-term stabilization by vegetation, and buffers are necessary because of adjacent residential land uses. Site preparation should include inventory and salvage of existing and spontaneously recruited (seed bank) native plant species that may emerge during nonnative vegetation removal. Preparation must also include eradication of invasive nonnative species prior to reintroduction of San Francisco lessingia. San Francisco lessingia from the Presidio population should be used as founders of the new colonies at Sutro Heights because they are close geographically, and because the Presidio plants were historically collected from equivalent ecological conditions (spray-exposed Colma Formation sandy bluffs; Table 1). Restoration and reintroduction methods should approximately follow those of Fort Funston.

The first recovery tasks for the Sunset Heights Recovery Unit must be to secure the sites for conservation of dune vegetation and reintroduction of San Francisco lessingia. Cooperative agreements should be established with the City of San Francisco Department of Parks and Recreation to manage invasive nonnative vegetation (eradicate iceplant and tall veldtgrass in particular), and to cut back nonnative woody vegetation encroaching the margins of the existing dune remnant at Sunset Heights Park. A vegetation management fund should be established for the maintenance removal of nonnative invasive vegetation at these sites. It is not clear whether seed to found the new Sunset Heights population should come from the Merced/Oceanview (Daly City) historic localities or the Presidio/Lone Mountain. Sunset Heights is slightly closer to Daly City, but its dune soils and local climate are more similar to those of the Presidio. It would be appropriate to conduct preliminary experimental transplants from both sites and monitor them on site to determine whether adaptively significant differences can be detected between source populations. Preliminary tests of within-species “hybrid” Daly City/Presidio plants would also be appropriate, comparing growth and reproductive output with parent populations here. If both population sources are equally fit at these sites, either the Daly City or a mixed Presidio/Daly City founder population may be appropriate, allowing natural selection and chance factors over time to compose the structure and composition of the new population. If available, population genetic data estimating the level of genetic differentiation between the Daly City and Presidio sites may also be considered in decisions on seed sources for Sunset Heights populations.

Management plans for vegetation at satellite reserves should be prepared and implemented with public notice and participation. The Hawk Hill site should be managed by the City of San Francisco (Parks and Recreation), or to a nonprofit conservation trust or government resource agency. Privately owned portions of the Sutro Heights sand slopes should be acquired and transferred either to the Golden Gate National Recreation Area, San Francisco Department of Parks and Recreation, or a qualified nonprofit conservation trust. This site also should be endowed with funds for maintenance in perpetuity. The sites should be monitored following the general prescriptions for the Presidio Unit. The satellite populations should be treated initially as though experimental populations.

2. Recovery Strategy for Raven's Manzanita

The recovery of Raven's manzanita, like that of San Francisco lessingia, is based on dual conservative and experimental approaches, emphasizing both protection of existing populations in enhanced existing habitat, and experimental establishment of new populations in restored habitat. The Presidio Unit's recovery actions are primarily conservative: they stress the survival of the remnant natural clone and its daughter clones, with vegetation management to suppress excessive competition from invasive nonnative plants. The San Francisco Unit's recovery actions are primarily experimental, though probably feasible, based on horticultural experience with native San Franciscan manzanitas. These actions consist of: (1) selecting undeveloped (usually undevelopable) rock outcrop sites (mostly serpentine) in the city that support either sparsely vegetated, bare, or predominantly weedy vegetation; (2) preparing the sites for reintroduction of native manzanitas (including Franciscan manzanita) and native associates; and (3) establishing populations of new genetic individuals of Raven's manzanita and associated species of rock outcrops (particularly serpentine). Recovery actions at interior San Francisco sites also include measures to minimize pollen flow from planted ornamental manzanitas. These replicated mixed populations of native manzanita would be actively maintained during establishment periods, then allowed to grow (or fail) independently, with low-level maintenance. They would be monitored for many years to track growth and (expected) sexually reproduced generations.

This recovery approach has two important milestones: (1) establishment of additional replicate clones of the remaining wild Presidio plant at many independent sites, not just clustered around the parent plant, to avoid extinction from localized events; and (2) establishment of multiple generations of genetically-variable individuals in sexually reproducing populations. The first steps toward spreading the risk of extinction among multiple cloned populations of the Presidio plant have been taken by the Golden Gate National Recreation Area and the U.S. Army, which have already planted 50 daughter clones near the mother clone and at 3 other Presidio locations (Golden Gate National Recreation Area unpublished data). However, most of these are subject to risks of spatially dependent mortality such as disease, fire, vandalism, trampling, and insect damage. This initial effort needs to be extended by more widespread establishment of additional daughter clones to variable serpentine outcrops of the Presidio.

New genetically variable populations should be established to approximate the unknown number of extirpated populations of Raven’s manzanita from interior San Francisco bedrock outcrops (at least four have been documented). The new populations should be in a variety of microclimates, generally warmer and drier than the Presidio. Because of the scarcity of suitable reintroduction sites, removal of nonnative trees will probably be necessary for reintroduction experiments. New populations of Raven’s manzanita should be established by sexual reproduction (seed) in order to produce variable new genetic individuals (as opposed to clones from cuttings). The first priority for recovery should be to establish viable inbred lines of Raven’s manzanita, if possible (D. Elam, pers. comm. 1999), through artificial self-pollination in controlled conditions. The ratio of viable seed per self-pollinated flowers, the germination and survival rates of any inbred seedlings, and the variability of any surviving inbred plants (genetic, morphological, and growth characteristics in variable substrates and microclimates) should be investigated. Any new inbred genetic individuals should be carefully labeled, catalogued, and kept in cultivation. Individuals determined to be suitable for reintroduction should be propagated clonally.

If it proves infeasible to produce adequately fit offspring that are genetically variable through self-pollination of the single surviving Presidio clone, it will be necessary to either abandon the objective of achieving sexually reproducing populations of Raven’s manzanita, or try alternative breeding methods to generate sexually reproducing populations with increased genetic variability. Breeding strategies based on introgression, or recurrent selection of introgressed hybrids (see Recovery Strategy, page 74) could be attempted with closely related taxa that are ecologically and morphologically similar to Raven's manzanita, emphasizing individual parent plants that are particularly similar. These strategies should be evaluated as described above for inbred Raven's manzanita. Recommendations on any potential breeding programs involving Raven's manzanita should be made by a scientific peer review panel with expertise in manzanita biology, plant conservation genetics, and plant breeding, after new scientific data on species' systematics and reproductive biology (described in recovery criteria) becomes available. The panel should also develop a genetic management plan for the species. Any experimental backcrossed hybrid derivatives of Raven's manzanita produced must be kept carefully isolated from Presidio populations. Tamalpais manzanita (*Arctostaphylos montana*) is presumably the most appropriate potential hybrid parent (based on current understanding of manzanita taxonomy, biogeography, and ecology) but other manzanita species should be evaluated as well, based on prior molecular genetic, ecological, and morphological comparative studies.

Other recovery actions include investigation of the levels of genetic variation in Raven's manzanita compared with small populations of rare wild relative manzanitas; evaluation of new genetic individuals' ecological, morphological, and physiological variation; investigation of taxonomic relationships between this and related manzanita species; and horticultural research on propagation, transplanting, and establishment. Public education and outreach are also essential actions that must be coordinated with implementation of recovery actions involving habitat restoration and reintroduction.

a. Development of a New "Pure" Inbred Founder Population of Raven's manzanita. Since no natural seedling establishment of Raven's manzanita has ever been observed since it was rediscovered by Peter Raven in the 1950's, artificial seed propagation is the only potentially practicable way to obtain new genetic individuals to add to the population. Seedling survival rather than seed germination itself has limited production in past efforts at growing seed from open-pollinated Raven's manzanita (H. Forbes, pers. comm. 1999), so emphasis should be placed on: (1) ensuring that seed is produced exclusively from controlled artificial self-pollination; (2) providing intensive, high quality seedling aftercare of any inbred seedlings; and (3) promoting rapid growth and early cloning of new juvenile plants. Experimental treatments that shorten the juvenile phase and promote precocious sexual reproduction would benefit development of inbred lines. Annual intensive controlled pollination and seed production, seed collection and propagation of cultivated clones will be needed to augment seedling production.

Any new genotypes of inbred Raven's manzanita should be clonally replicated at multiple botanical gardens and the Golden Gate National Recreation Area's native plant nurseries, with mandatory permanent labeling and identification of clones and their pedigrees. New individuals should be maintained in permanent cultivated populations. If they are determined to be fit for use as stock for outplanting in new populations in San Francisco outside of the Presidio, replicated clonal stock populations should be maintained in cultivation. Golden Gate National Recreation Area nurseries at Fort Cronkhite and the Presidio would be well-suited facilities for the horticultural propagation and any breeding work. In addition, replicates of existing and future clones of inbred and cloned "pure" Raven's manzanita should be maintained in perpetuity at multiple botanical gardens in California, in relative isolation from other manzanita species. Seed of any inbred Raven's manzanita should be stored at local (Golden Gate National Recreation Area, University of California Botanical Garden, Berkeley) and other (Rancho Santa Ana) seed banks, following guidelines of the Center for Plant Conservation (1991). Cloned new genotypes should be tested for performance (growth, reproduction) in propagation, and in new interior San Francisco reintroduction sites.

b. Contingency Measures for Producing New Individuals: Introgressive Breeding of Raven's Manzanita. It is possible that self-pollination of clones of the single remaining individual may produce viable seed, and enough seedlings with adequate variability in ecologically important traits (e.g., growth habit, growth rate, soil chemistry tolerance, disease resistance) for natural selection to act upon. This outcome may be possible if the single clone is not a fully obligate outcrosser, and if it has a relatively high amount of latent genetic variation (many different forms of genes, or alleles, and multiple alleles for various genetic traits) as was the case for the single-founder, endangered showy indian-clover (*Trifolium amoenum*) (Knapp and Connors 1999). If, however, selfing produces no seed, or plants with inadequate fitness or poor adaptability to environments of reintroduction sites (e.g., high post-establishment mortality, weak competitive ability, unusually slow growth, disease susceptibility, nutrient deficiency symptoms in local serpentine soil), an alternative source of genetic variation may be developed by an introgressive breeding strategy (see Recovery Strategy, page 74). Introgressive breeding (Falk 1992) would be based on creation of hybrids with similar, closely related manzanitas, selection of hybrids, and backcrossing (crossing hybrids with one parent species) on to Raven's manzanita over multiple generations. Backcrossed individuals that are essentially indistinguishable from Raven's manzanita species (as in examples of natural introgression among other manzanitas; Ellstrand *et al*. 1987), but exhibit a wider range of variability, would be selected repeatedly. This variation on a "captive breeding" strategy for plants is a tactic of last resort, justified only when populations are so reduced that reproduction of genetically viable generations is practically infeasible (Rieseberg 1991, Falk 1992).

Introgression among manzanita species occurs in nature, and in some cases results in individuals that are essentially indistinguishable from parent taxa, even in specialized serpentine species. Gottlieb (1968), examining populations of serpentine-endemic whiteleaf manzanita (*Arctostaphylos viscida*), found only a few of its hybrids on serpentine soil, and noted that these presumed introgressants closely resembled *A. viscida*. Ellstrand *et al.* (1987), studying natural hybridization in *A. viscida* ssp. *mariposa* and *A. patula*, found that most introgressants were physiologically similar or indistinguishable from parent species. They also found that true hybrids (first-generation species crosses) and segregants (progeny of hybrids breeding among themselves) were rare. Kruckeberg (1977) observed that the frequent generation of hybrid *Arctostaphylos* ×*media* (from *A. columbiana* and *A. uva-ursi*) did not appear to cause genetic contamination of the parent species by gene flow through introgressants. In the absence of experimental data from Raven's manzanita, it is unknown whether these natural analogues are relevant to the specific case of Raven's manzanita. The decision to introduce artificially bred introgressant forms of Raven's manzanita to isolated, newly restored urban reserves must involve scientific peer review by botanists with expertise in manzanita systematics and ecology, and in population genetics of rare plants, based on research outlined above.

A comparable "single founder" challenge to endangered plant species recovery has recently been investigated in the federally endangered showy Indian clover (*Trifolium amoenum*), a "presumed extinct" species (Isely 1993) that was believed to have been reduced to a single known fertile individual when it was rediscovered at an inland location in Sonoma County, California. A second wild coastal population of 20 plants was subsequently discovered. In this case, a surprising amount of genetic variation (as polymorphism of alternative genes [alleles] for forms of proteins called allozymes) was detected within the lone survivor of the inland population (Knapp and Connors 1999). Over 50,000 viable seeds were derived quickly from self-pollination of the single known surviving plant, and seedlings thrived in cultivation. In this case, strong ecological and morphological contrasts between the two known populations suggested that benefits of increasing genetic diversity by simple hybridization of distinct inland and coastal ecotypes (ecological races) would be outweighed by the risks of producing maladapted hybrid offspring, and a decline in fitness (outbreeding depression). This ecological adaptation issue may be moot for Raven's manzanita and Tamalpais manzanita, both of which inhabit serpentine outcrops near the coast around the Golden Gate. The systematic relationship between these two closely related manzanitas, however, is an open question (Markos *et al.* 1999). Additional research will be necessary to determine whether Raven's and Tamalpais manzanita constitute one species with distinct populations, subspecies within a species (as recently interpreted; Wells 1993), or different species altogether.

The use of hybridization to any degree in the genetic management of an endangered plant species (even a sole surviving individual) is likely to be controversial since there are no actual precedents, but only proposals. Knapp and Connors (1999) suggested that a breeding program of controlled experimental introgression that entails repeatedly crossing a series of hybrids (distinct populations within the species) back on to one parent population might provide a means of balancing the needs for genetic variation and adaptive integrity in showy Indian clover. Rieseberg (1991) suggested that hybridization might be useful in captive breeding programs as a "last-ditch" effort to conserve endangered species. Barrett and Kohn (1991) recommended experimental approaches to reintroduction of rare plants that involved both "pure samples" from existing populations as well as "composite [within species] mixtures with greater genetic variation," noting the uncertainty of theoretical predictions regarding genetic management of "pure" or mixed founders of reintroduced populations. Reintroducing experimental populations of both "pure" and "mixed" genetic individuals at isolated locations would enable scientific testing of how well the compromise strategy works (Knapp and Connors 1999, Guerrant 1996). The appropriateness of the use of hybridization in genetic management of Raven's manzanita may depend to a significant degree on how closely related it is to manzanitas considered as candidates for hybridization.

Because of the natural ecological and geographic isolation of serpentine outcrops in interior San Francisco, and lack of natural seedling establishment of Raven's manzanita after 5 decades of observation, it is unlikely that experimental introgressive breeding, if implemented, would pose genetic risks to the natural coastal Presidio plant. This assessment is also suggested by the integrity of parent manzanita species immediately outside the edges of their hybrid zones (Gottlieb 1968, Kruckeberg 1977, Ellstrand *et al*. 1987). Any introgressive hybrids of Raven's manzanita must be carefully maintained and labeled (with parentage) at Service-approved botanical gardens or nurseries dedicated to either research or native plant restoration. Seed of any introgressive hybrids should be stored at local (Golden Gate National Recreation Area, University of California Botanical Garden, Berkeley) and other (Rancho Santa Ana) seed banks, following guidelines of the Center for Plant Conservation (1991).

c. Site Selection and Acquisition for New Populations in San Francisco. Suitable candidate sites should be assessed for pilot reintroduction projects. Sites should be selected based on information obtained by completing detailed field surveys, and applying the following criteria (in order of priority): (1) presence of serpentine bedrock outcrops within open space areas that have potential for vegetation management or restoration, (2) presence of greenstone (basalts or similar volcanic rocks with mafic chemistry) outcrops within open space areas, and (3) presence of other Franciscan rock outcrops with thin or minimal soil development. Suitable sites would include steep slopes. Additional factors that may affect selection of candidate sites include feasibility of nonnative plant removal and subsequent control and management; minimization of local land use conflicts or local opposition to removal of nonnative vegetation (especially trees); and local support for vegetation management.

Likely areas for candidate sites within the Fort Point/Hunters Point serpentine belt include Bayview Hills, Potrero Hills, the U.S. Mint at Duboce Street, slopes behind Crissy Field (Presidio), and slopes between Fort Point and Baker Beach (Fort Scott) (Figure 2 and Figure 3). Sites would likely include road cuts or old excavations. Greenstone sites are likely at Mount Davidson Park, and Mount Sutro. Potrero Hills is a particularly suitable potential reintroduction area. Although it is not a specific historic locality of manzanitas, it contains some conserved open-space serpentine outcrop sites within the same serpentine belt as historic populations (Figure 3). Other sites with likely potential bedrock outcrops suitable for experimental reintroduction of native manzanitas include mixed Franciscan rock outcrops Corona Heights, Twin Peaks, Sunset Heights, McLaren Park, and Point Lobos.

Following site evaluation and selection, sites should be acquired so that habitat restoration and reintroduction of native manzanitas and their associated rock outcrop flora can be implemented. Management plans must be prepared for each reserve. Maintenance of each reserve should be ensured by selecting an appropriate manager, initiating local stewardship programs, and endowing the site with a maintenance and monitoring fund.

d. Control of Cultivated Manzanita Pollen Flow and Spontaneous "Nonnative" Hybrids. Full recovery of Raven's manzanita (and reestablishment of Franciscan manzanita) would require local removal of nonnative manzanitas within likely pollinator flight distances of transplanted Raven's manzanita populations to prevent their reproduction from being "swamped" by pollen from abundant planted manzanitas, resulting in the Raven's manzanitas producing predominantly hybrid seed (Levin *et al.* 1996). Pollinator distances for significant gene flow among manzanita populations would be difficult to estimate, and would be geographically specific. Scientific estimates should be obtained by site-specific research. Alternatively, a ban on planting other manzanita species in the western quarter of the Presidio may be used as a practical surrogate for unavailable scientific data, based on best professional judgement. Reducing potential "pollen swamping" near reintroduction sites should be achieved by public education, outreach, and cooperation, with the assistance of local conservation organizations. In contrast, some or most transplanted populations of Raven's manzanita outside the Presidio should be interplanted with Franciscan manzanita, its historic associated species. Newly established populations of Raven's manzanita should be monitored closely for reproductive output (seed production) and success (seedling establishment) over a period of decades (multiple generations).

e. Identification and Permanent Protection of Existing and Potential Serpentine Habitat in the Presidio. In order to conserve these scarce serpentine outcrop resources for future potential establishment of native manzanita populations, surface exposures of serpentine rocks and soils in the Presidio should be: (1) surveyed, (2) assigned reasonable buffers in consultation with the Fish and Wildlife Service under the Endangered Species Act, and (3) automatically transferred to the Golden Gate National Recreation Area if not retained by the Presidio Trust in the future. Both the Trust and Golden Gate National Recreation Area should maximize opportunities to conduct habitat restoration and reintroduction of Raven's manzanita to these sites. Areas within the Presidio bearing outcrops or near-outcrops of serpentine bedrock should not be transferred to the U.S. General Services Administration for disposal. At the present time, legislation authorizing the Presidio Trust does not preclude such transfers.

f. Public Outreach and Education. Public outreach and education are needed for the long-term recovery of Raven's manzanita, primarily to develop support and cooperation for restoration and reintroduction actions, and to avoid opposition to the changes in the urban landscape that are necessarily part of restoration projects, such as removal of nonnative trees. Both tree removal and reintroduction of federally endangered species may encounter local opposition, which means that collaborative outreach and education programs are essential prior to initiation of recovery projects. These programs can utilize local schools, nonprofit conservation and horticultural organizations, and should include a program to promote appropriate ornamental horticultural use of native manzanitas (other than federally or State listed taxa). Local broadcast and print media can explain the need and purpose of restoration actions, and might promote the esthetic benefits of improved scenic views following removal of nonnative trees. Local stewardship programs, many of which exist even now in potential reintroduction sites, can provide highly valuable long-term maintenance and monitoring through stewardship programs. Authorized public demonstration gardens can serve as auxiliary botanical gardens for local neighborhoods, familiarizing local residents with Raven's manzanita and providing reassurance that reintroduction will not cause restrictive regulatory burdens or changes to recreational land uses. Appropriate horticultural use of endangered plant species as a tool for public outreach in recovery has been proposed for the endangered western lily (U.S. Fish and Wildlife Service 1998).

g. Additional Research. Long-term research is particularly needed to determine appropriate management of the species. Applied research tasks in addition to those identified for breeding and reintroduction (see (b) above) should include ecophysiological studies to evaluate basic environmental growth responses (growth under variable soil/bedrock types, mycorrhizal function, competition, slope, aspect) of the species. Investigation of the reproductive ecology, particularly seed germination, seedling establishment, seed set, seed dispersal, and pollination, are needed to predict and manage conditions necessary for spontaneous seedling recruitment. Practical research needs also include locally appropriate methods of controlling invasive nonnative vegetation.

3. Conservation Recommendations

The following conservation recommendations are directed at species of concern and conservation significance. These species are the vanishing components of the local dune remnants and thinly vegetated bedrock outcrops of San Francisco that were discussed in Chapter III.B. These recommendations should be integrated with the recovery tasks that are aimed at federally listed species, to assure that the recovery tasks result in community-level protection, management, and restoration actions.

General tasks for species of concern or conservation significance include the following:

> (1) Survey potential restoration sites, including seed bank probes (germination tests of shallow soil sample cores) for the presence of target species. Survey appropriate habitat for target species within San Francisco. Surveys should be conducted over multiple years, including drought and high rainfall years. If surveys are negative over several years, or if remnant populations are small and at least regionally rare, expand surveys to nearest suitable habitat within the species' geographic range.
>
> (2) If lands supporting viable populations of species of concern are unprotected or adversely managed or neglected, acquire or protect parcels as reserves.

(3) Enhance habitats supporting target species where they have been degraded by influences such as invasion by nonnative plants, excessive trampling or off-road vehicle or dirt bike use, or other threats.

(4) For species that are extirpated (or nearly so) in San Francisco, collect seed from closest geographic populations in ecologically equivalent habitats, when source populations are large enough not to be impaired by sampling of approximately 50 to 100 seeds, or clones of approximately 50 individuals. Samples should be obtained randomly throughout the source population, equalizing numbers of propagules (seeds, cuttings, etc.) from each plant sampled. Plants should be propagated in native plant nurseries for reintroduction or augmentation of San Francisco populations, following expert scientific peer review of reintroduction/augmentation plans (including detailed, specific taxonomic and ecological evaluation). Augmentation plans may also include a provision for low-level dispersal (immigration) of seeds or plants to habitats that have been fragmented by urban development, but still contain small, isolated populations.

(5) For target species that persist in San Francisco, apply management actions to reduce the principal impediments to the persistence or re-expansion of populations, such as invasive nonnative vegetation, adverse soil modifications (irrigation, fertilization, leaf litter of nonnative vegetation), and excessive trampling. Population augmentation by transplanting nursery-propagated stock should be attempted only if effective habitat enhancement fails to promote viable populations; planting should not be used as a primary method of conserving remnant populations of target species.

(6) For rare target species with chronically or periodically small populations, maintain either stored seed, or pedigreed clones in cultivation, as appropriate for the life-history of the species.

(7) Conduct research on species-specific techniques for propagation, transplanting and establishment techniques, microenvironmental requirements, and species associations (competitor, mutualist, pollinator relationships).

V. STEPDOWN NARRATIVE OF RECOVERY TASKS

A. San Francisco Lessingia

A 1. Protect, maintain, and enhance existing populations and habitat.

A 1.1. Protect and manage populations on the Presidio

A 1.1.1. Develop and implement general and specific management plans. Work with the Golden Gate National Recreation Area to complete tasks A 1.1.1.1 through A 1.1.1.4 below.

A 1.1.1.1. Modify the Presidio Vegetation Management Plan to prescribe maintenance and enhancement activities consistent with this recovery plan for all lessingia sites of the Presidio. (Priority 1)[3]

A 1.1.1.2. Delineate and permanently dedicate Golden Gate National Recreation Area and Presidio Trust lands identified in this recovery plan (including prospective restoration areas) to management of dune vegetation supportive of San Francisco lessingia. (Priority 1)

A 1.1.1.3. Develop and implement site-specific management plans, including monitoring, for the Lobos Dunes, Battery Caulfield, Marine Hospital, Rob Hill, and Wherry Dunes populations of San Francisco lessingia. (Priority 1)

A 1.1.1.4. Commit timely and adequate resources to implement vegetation management plans affecting San Francisco lessingia, sufficient to achieve interim recovery criteria. Reduce invasive nonnative vegetation to low and insignificant levels, or

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[3] Task priority is defined at the beginning of the Implementation Schedule on page 189.

eradicate them completely if possible, at all San Francisco lessingia sites. (Priority 1)

The management plans should be developed collaboratively among Golden Gate National Recreation Area, The Presidio Trust, California Department of Fish and Game, and the U.S. Fish and Wildlife Service, with public outreach, review, comment, and lead agency response to comments. Management plans should comply with the recovery strategy outlined above, and should apply to both Golden Gate National Recreation Area and Presidio Trust lands that are proposed to support San Francisco lessingia in the future. Plans should address vegetation management techniques (e.g., herbicide use, manual weed removal, managed or semi-natural disturbance regimes, trampling intensity, public access and rotational trail closures, and experimental modification of established policies).

A 1.1.2. Monitor all Presidio populations. Monitoring of San Francisco lessingia populations should be integrated into management plans (task A 1.1.1). Monitoring should be conducted annually until recovery criteria are met for the Presidio Recovery Unit. After the criteria are met, results will be evaluated to determine the frequency and intensity of further monitoring. Monitoring methods should include periodic false-color, infrared vertical aerial photographs of each site, quantitative stratified sampling of vegetation, and annual census of mature plants, plus some population sampling and analysis of reproductive output. Monitoring should also focus on problem areas for invasive nonnative plants. (Priority 2)

A 1.1.3. Establish permanent and seasonal staff dedicated to lessingia vegetation management. Establish and fund a permanent full-time vegetation technician to implement and oversee maintenance (and restoration) at all Presidio populations. The position should be funded at least until recovery criteria for the Presidio Recovery Unit are met. This technician should coordinate efforts with analogous dune management activities at Fort Funston. Establish seasonal vegetation technical positions in support of the full-time technician as needed. (Priority 1)

A 1.2. Protect the Daly City population.

A 1.2.1. Protect the Daly City population under its existing ownership. Establish interim or permanent cooperative agreements, or conservation easements, with the Daly City site's private and municipal landowners to protect the site against adverse land uses, and to enable implementation of beneficial maintenance and enhancement activities (principally control of invasive nonnative vegetation). (Priority 1)

A 1.2.2. Acquire Daly City parcels within proposed San Francisco lessingia reserve. Acquire Daly City parcels supporting San Francisco lessingia, associated species, as well as restorable habitat on the sand slopes above Hillside Park and Bonnie Street, to ensure permanent protection and ability to manage the site without conflicts of land use. (Priority 1)

A 1.2.3. Establish a land manager and endowment fund for site management. Select a permanent land manager and provide an endowment to maintain and manage the site. Maintenance and management obligations would include control, progressive removal and reduction of nonnative vegetation, erosion control, regulation of pedestrian access, public education and nature interpretation, population monitoring of San Francisco lessingia, and coordination with neighbors and the U.S. Fish and Wildlife Service. (Priority 2)

A 1.2.4. Prepare and implement a long-term management and restoration plan. Prepare a site-specific management plan according to the general management and (limited) restoration prescriptions of this recovery plan. The content of the plan should correspond with that of the Presidio specific plans (task A 1.1.1.3). Implement the plan in perpetuity. (Priority 2)

A 2. Restore habitat and reintroduce San Francisco lessingia at designated reserves.

A 2.1. Prepare plans for habitat restoration and augmentation or reintroduction of populations. Prepare comprehensive restoration plans for San Francisco lessingia and reintroduction or augmentation plans at the reserves specified below. Planning for Presidio sites that are proposed for consolidation with the Lobos dunes reserve should prepared jointly, so these sites will form a unified, phased complex, rather than independent units, each with its own plan. Plans should implement general conceptual designs. For example, plans should specify tasks for seed bank assessments of weeds and native species; native plant/seed bank recruitment salvage where appropriate; nonnative tree and iceplant removal; duff and debris removal (including removal of organically enriched surface soil layers); weed seed bank exhaustion; topographic recontouring; temporary post-grading dune stabilization; composition, pattern and density of local native species transplanting; pattern and density of San Francisco lessingia seeding; and contingency measures (including options for delay of reintroduction) in case of drought or catastrophic failures. (Priority 2)

A 2.2. Expand populations and restore habitat at designated San Francisco lessingia reserves.

A 2.2.1. Expand population and restore habitat above Lobos dunes site. Remove all Monterey cypress and iceplant on dune slopes above (north and east) of Lobos Creek, to Battery Caulfield Road (linking the San Francisco lessingia relict population there), prepare and recontour slopes of dune sand surface, exhaust invasive weed seed/bulb banks, and reintroduce native dune scrub and grassland vegetation with San Francisco lessingia, in patchy, low density initial populations. Establish a consolidated, expanded Lobos Dune population of San Francisco lessingia, according to the plan for this reserve (task A 2.1.1). (Priority 1)

A 2.2.2. Expand populations and restore habitat from Lobos Dune site to Baker Beach dunes. Incrementally remove the Monterey pine and cypress grove from the north end of Baker Beach, including removal of duff/leaf litter removal (but no recontouring), following the restoration plan for this site (treated as part of the Wherry site). These actions will open wind fetch for the Wherry Dunes and open habitat for dune scrub supporting San Francisco lessingia. Establish a roadside buffer zone of transplanted native woody dune scrub vegetation, but allow natural recolonization by native dune scrub, along with active suppression of invasion by nonnative species there; or establish only patchy distribution of native dune scrub vegetation by limited transplanting of locally propagated populations if natural recruitment is inadequate. Establish multiple founder colonies of San Francisco lessingia at the same time as pioneer species are being extirpated. Remove nonnative conifers from upper dune slopes near Lincoln Boulevard at the south end of Baker Beach to re-open wind fetch for expanded Lobos Dune habitat. Establish a consolidated, expanded Lobos dune population of San Francisco lessingia with higher long-term viability, according to the plan for this site (Task A 2.1.1). (Priority 1)

A 2.2.3. <u>Expand populations and restore habitat from Lobos Dunes Reserve through Wherry Housing area (Lobos/Wherry/Baker Reserve)</u>. After Task A 2.1.3 is implemented, begin the previously-planned phased demolition of Wherry Housing, and implement the restoration/ reintroduction plan for this portion of the Presidio Recovery Unit. Establish a consolidated, expanded Lobos dune population of San Francisco lessingia with higher long-term viability, according to the plan for this complex (Task A 2.1.1). (Priority 2)

A 2.2.4. <u>Expand populations and restore habitat at the Marine Hospital lessingia Reserve</u>. Remove the Monterey pine and iceplant understory north of the Marine Hospital, and remove duff/leaf litter layer, following the restoration plan for this site. Reintroduce sparse dune scrub and grassland vegetation with San Francisco lessingia according to the plan for this reserve. (Priority 2).

A 2.2.5. <u>Expand populations and locally restore/enhance habitat within the Daly City lessingia Reserve</u>. Incrementally eradicate iceplant and annual nonnative grasses on the Hillside Park sand slopes, following the restoration plan for this reserve. To prevent excessive slope destabilization, work upslope in increments, and facilitate natural recolonization by dune scrub vegetation, or transplant locally propagated natives. Establish a mosaic of bare patches in slopes dominated by nonnative vegetation (such as horseweed, annual grasses), and suppress nonnative vegetation while establishing a new matrix of dune scrub vegetation around bare patches. Sow a mix of native annual seed including local San Francisco lessingia in bare patches. (Priority 2)

A 2.2.6. Restore habitat and reintroduce San Francisco lessingia to dunes at Fort Funston/Lake Merced. Incrementally eradicate iceplant and nonnative conifers and scrub at Fort Funston (Golden Gate National Recreation Area) and reintroduce San Francisco lessingia from Daly City according to the plan for this site (Task A 2.1). (Priority 2)

A 2.3. Establish beach layia (*Layia carnosa*) to the Fort Funston lessingia Reserve for San Francisco lessingia. Integrate establishment of beach layia (federally endangered) with lessingia reserve at Fort Funston, consistent with its recovery plan (U.S. Fish and Wildlife Service 1998*b*). Beach layia seed source should be the core population from Point Reyes. (Priority 2)

A 2.4. Establish new San Francisco lessingia population(s) at restored satellite reserve dune remnants.

A 2.4.1. Secure the Hawk Hill site dune remnant in Sunset Heights. Acquire the Hawk Hill site from willing sellers and transfer title to either a public or nonprofit entity dedicated to long term natural area management and stewardship, with deed restrictions ensuring its conservation as a reserve for rare dune species, or establish a comparable conservation easement. Endow the site with a fund sufficient to generate enough interest to support long-term vegetation management to prevent reinvasion of dominant nonnative vegetation. (Priority 2)

A 2.4.2. <u>Secure privately owned portions of sand slopes and dunes near Sutro Heights that are needed for this satellite reserve</u>. Either acquire the privately owned portions of the sand slopes near Balboa Street and 48th Avenue from willing sellers, or establish conservation easements that enable management of the site as a lessingia reserve. If acquired by fee-title, transfer title to either Golden Gate National Recreation Area or the City of San Francisco, with deed restrictions ensuring its conservation as a reserve for rare dune species. Endow the site with a fund sufficient to generate enough interest to support long-term vegetation management to prevent reinvasion of dominant nonnative vegetation. (Priority 2)

A 2.4.3. <u>Control or eradicate invasive nonnative vegetation within satellite reserves</u>. Incrementally eradicate iceplant, jubata grass, ripgut brome, and other invasive nonnative plants at Hawk Hill and Sutro Heights reserves. Remove Monterey cypress trees and veldtgrass understory at Grandview Park. Expand margins of Sunset Heights Park dune remnant by cutting back nonnative shrubs and trees along its periphery. Remove acacias, albizias, cypress and iceplant from the Cliff House sand slope, and install appropriate native buffer scrub vegetation around residential areas there. (Priority 2)

A 2.4.4. <u>Establish San Francisco lessingia in satellite reserves</u>. In areas where nonnative invasive vegetation has been cleared, establish founder populations of San Francisco lessingia at Hawk Hill and the Cliff House sand slopes, and at least one of the two other remnant dune habitat sites. Manage vegetation to a condition in which San Francisco lessingia spontaneously regenerates and colonizes. (Priority 2)

A 3. <u>Conduct public outreach, education, and coordination</u>.

A 3.1. <u>Prepare information presentations for public outreach</u>. Prepare scientifically accurate graphic, written, and oral accounts of the needs for species recovery, the needs for habitat restoration, and the time and spatial scales involved. Use endorsements (written statements of official support) of restoration/reintroduction plans by government natural resource agencies and nonprofit conservation groups for dissemination and information packages to media, neighbors of reserves, and other interested public citizens. Present information through public meetings, news media, and mailings. (Priority 2)

A 3.2. <u>Conduct public outreach meetings prior to implementation of major recovery tasks</u>. In advance of any tree removal, large-scale vegetation management, or reintroduction tasks, engage in substantial promotional public outreach programs using local media, formal public notice, and public meetings. Use media materials from task A 3.1. (Priority 2)

A 3.3. <u>Publicize and promote restoration sites prior to conspicuous site modifications</u>. Well in advance of site restoration actions, place informational signs (or brochure dispensers) around restoration sites explaining prospective actions and results. Include visual displays (photographic, diagrammatic) in signs. (Priority 3)

A 3.4. <u>Publicize project effects on scenic views and recreational use of the Golden Gate and Presidio</u>. Provide specific written, visual, and media accounts of restoration projects' compatibility (or incompatibility) with recreational uses of these areas where restoration/reintroduction plans are perceived to threaten established or locally popular recreational or esthetic land uses (e.g., public access, dog walking at Fort Funston; forested viewsheds of northern Presidio). Provide interpretive visual displays of scenic values of viewsheds of Golden Gate, comparing views under forested and restored dune (tree removal) conditions. Provide explanatory accounts of temporary exclosures during transplanting/establishment phases of restoration, and extent of long-term public access. (Priority 2)

A 3.5. <u>Actively support public volunteer participation</u>. Promote and provide Federal support (staff, funds) for public volunteer participation in monitoring and site stewardship (vegetation management) activities, in coordination with local nonprofit conservation organizations, particularly ones with volunteer site stewardship programs in progress. (Priority 3)

A 4. Conduct research in support of San Francisco lessingia recovery. San Francisco lessingia habitat restoration, including both deliberate and accidental reintroduction actions in the Presidio, began before the species was listed. Before the results were available from scientific studies of the species' life-history and competitive interactions, restoration efforts were based on professional judgement of habitat needs and observation of dispersal. These efforts were nonetheless extremely successful, at least in the short-term. Additional research may improve the long-term prospects for success, but such research is not a prerequisite for initiating additional restoration and reintroduction actions based on the practical, empirical results of the pilot projects at Lobos Dunes, and the success of the unplanned introduction at Wherry Housing. Additional research should be aimed at refining restoration and reintroduction techniques, controlling nonnatives, establishment of suitable dune topography and mobility, and critical aspects of the species' ecology and taxonomy.

A 4.1. Study variation in ecological and genetic characteristics of San Francisco lessingia. Study patterns of population variation in significant ecological traits among and within relict populations, and compare with reintroduced populations, including both field and common-garden approaches. Determine whether significant genetic differentiation occurs within or between San Francisco lessingia populations or colonies, and assess patterns of genetic diversity. Use the results to guide decisions about seed sources for satellite reserves, and controlled mixing of artificially isolated populations in the Presidio. (Priority 3)

A 4.2. Study rates and modes of recolonization by invasive nonnative plants, and control methods. Study rates and modes of recolonization by invasive nonnative plants (Appendix III) and methods of control, including seasonal variation in all applied techniques. Techniques should include manual removal, applications of synthetic herbicides appropriate for use in parks (including glyphosate and grass-specific herbicides), natural foliar desiccants (e.g., vinegar), and in some locations, earthmoving equipment (scraping, burial). (Priority 2)

A 4.3. Study the pollination ecology of San Francisco lessingia. Determine the mode and vectors of pollination that contribute most to seed production. (Priority 3)

A 4.4. Experimentally investigate feasibility of rotational trail closure / temporary pedestrian exclosure as vegetation management technique. Study rotational closure and opening of pedestrian trails and exclosures to determine the potential efficacy of intermittent (among years) seasonally timed intensive trampling as a method of maintaining disturbed semi-open dune vegetation favorable to native annual dune plant species, including San Francisco lessingia, at locations with high demand for recreational access (e.g., Fort Funston). (Priority 2)

A 4.5. Conduct field experiments on restoring and anthropomorphically managing dune topography. Conduct field experiments on managing and restoring dune topography and mobility within the land management constraints of the Presidio and Fort Funston, aimed at establishing undulating to steep dune topography and mosaics of persistent, limited blowout activity that are suitable for San Francisco lessingia regeneration and colonization. Determine rates of erosion and deposition at spatial scales favorable to the species under field conditions. (Priority 2)

A 4.6. Study seed dispersal and seed bank ecology of San Francisco lessingia. Study recruitment of different age-classes of seeds, longevity of dormant seeds, and seed dispersal. (Priority 3)

A 4.7. Study effects of substrate conditions on growth and reproduction of San Francisco lessingia. Compare growth and reproduction on natural variation in local substrates (young dune, old dune, Colma Formation sand). Study effects of sand mineral nutrition, mycorrhizae, slope aspect, microclimate), comparing differences between Presidio and Daly City populations. (Priority 2)

A 4.8. Clarify taxonomic relationships between San Francisco lessingia and allied species. Assess the biosystematic relationship between San Francisco lessingia and similar species (e.g., *Lessingia glandulifera* varieties). (Priority 3)

A 5. Offsite conservation measures.

A 5.1. Establish cultivated populations. Establish cultivated populations of San Francisco lessingia at regional botanical gardens for study (providing sources of seed and herbarium specimens for research, alleviating some need for harvest of wild populations) and public education. (Priority 3)

A 5.2. Maintain stored seed bank to ensure survival in case of population failure in reserves. Collect seed from each Daly City and Presidio populations annually for deposit in seed banks certified by the Center for Plant Conservation, as well as for distribution to local conservators approved by U.S. Fish and Wildlife Service (e.g., Golden Gate National Recreation Area, Strybing Arboretum). Periodically test lots of old seed for germinability. (Priority 3)

B. Raven's Manzanita

B 1. Protect, maintain, and enhance the relict natural clone of Raven's manzanita at the World War II Memorial, Presidio.

B 1.1. Control nonnative vegetation. Suppress nonnative invasive plants in serpentine grassland and scrub around the natural clone of Raven's manzanita. Aim at local eradication of nonnative vegetation, but achieve at least suppression to insignificant levels. Aim at keeping invasion front at least 30 meters (100 feet) away from Raven's manzanita. Prohibit use of any herbicides that affect broadleaf plants within 30 meters (100 feet) of the manzanita to avoid any possible contact with herbicide drift. (Priority 1)

B 1.2. Monitor growth, reproduction, and clone size of Raven's manzanita annually. Monitor flower production, timing, insect visitors to flowers, seed set, and seed dispersal. Monitor growth at areas of contact with above ground parts of competing shrubs. (Priority 2)

B 1.3. Manage native vegetation. Based on monitoring of growth of Raven's manzanita, prune or remove competing native vegetation if it causes significant depression of growth of portions of the original clone or daughter clones. (Priority 2)

B 2. Protect, maintain, enhance, and increase transplanted Raven's manzanita populations in the Presidio.

B 2.1. Monitor growth and clone size of established transplants annually. The size of plants, rate of growth, and proportions of live and necrotic patches (blight-induced dieback) should be monitored at least once annually, and preferably at the beginning, peak, and end of each growing season. Production of flowers and fruit should be monitored annually. Fruit should be sampled annually to estimate production of viable seed. (Priority 2)

B 2.2. Control nonnative vegetation. Suppress nonnative invasive plants, and native shrubs, where necessary (see Task B 1.1), at sites of previous transplants along Lincoln Boulevard and Inspiration Point. Prohibit use of herbicides that affect broadleaf species within 30 meters (100 feet) of these sites to prevent damage by herbicide drift or accidental application. (Priority 1)

B 2.3. Survey and select additional serpentine outcrop sites for further transplantation of clones within the Presidio. Selected sites should include serpentine bedrock outcrops in relatively stable positions in the Presidio bluffs, and at least one additional location away from the bluffs. Criteria for selection include sparse vegetation, a lack of strong local invasion pressure by nonnative herbaceous vegetation, and absence of federally listed species or species of concern. Preference for reintroduction sites should be given to serpentine outcrops that lack significant native serpentine plant populations. (Priority 2)

B 2.4. Prepare sites as necessary for transplantation of propagated clones in the Presidio. To prepare sites, remove any nonnative trees within peak seed dispersal distance (all trees upwind to a distance of at least 90 meters [300 feet]) to avoid recolonization, shading, and fog drip effects. Remove all invasive nonnative shrubs and herbaceous species (particularly myoporum, iceplant, albizia, acacia, and jubata grass) within at least 300 meters (1,000 feet) upwind of the manzanita site; for jubata grass, a species with small plumed seeds that are highly capable of long-distance dispersal, all plants upwind should be eradicated). For sites restored under former tree cover, reintroduce native associated serpentine-affinity species from local sources. (Priority 2)

B 2.5. <u>Transplant replicated clones at selected prepared sites</u>. Transplant Presidio clones at selected reintroduction sites. Plant in groups to allow for mortality, and to increase attractiveness of the population to pollinators. If possible, include new clones propagated from seed from the original plant, or from controlled self-pollinated Presidio clones. Provide frequent monitoring (weekly) and intensive post-transplant care (including supplemental watering, mycorrhizal inoculation, and low-level application of nutrients, especially organic nitrogen) for one growing season, or two seasons if drought conditions prevail. At least 3 additional populations remote from the parent colony should be established, consisting of at least 10 replicate clones that survive and grow vigorously at least 5 years after transplanting. (Priority 2)

B 2.6. <u>Monitor transplanted replicated clones</u>. After establishment (beginning third growing season), monitor growth and survivorship of new transplanted clones at least four times annually. Shift to minimum annual monitoring after the fifth growing season. Monitor associated vegetation. Provide adaptive levels of vegetation management in response to nonnative species invasion. If sites fail due to interference from excessive growth of native serpentine grassland or scrub species, abandon the colony and replicate two additional reintroduction sites elsewhere in the Presidio Tasks B 2.1 to B 2.6). (Priority 2)

B 2.7. <u>Identify and protect known and potential serpentine outcrop sites</u>. Survey and permanently protect all serpentine outcrops and near-surface occurrences of serpentine in the Presidio against development to reserve them for future restoration and reintroduction. All serpentine sites should be managed by Golden Gate National Recreation Area natural resources staff, and should eventually be transferred to Golden Gate National Recreation Area. (Priority 3)

B 2.8. Reintroduce associated serpentine plant species. Incorporate reintroduction of other native serpentine grassland species in decline (or extirpated) in San Francisco. Include plans to reintroduce other federally endangered species, consistent with approved recovery plans (U.S. Fish and Wildlife Service 1998). Select stock from local San Francisco sources or closest serpentine habitats. (Priority 3)

B 3. Restore habitat and establish new populations in San Francisco outside the Presidio.

B 3.1. Evaluate and select candidate reserve sites for reintroduction around San Francisco. Priority should be given to bedrock outcrops within the Fort Point-Hunter's Point serpentine belt (Figure 3). The next highest priority should be greenstone (particularly basalts) outcrops. Lowest preference should be given to other Franciscan rocks lacking mafic or ultramafic chemistry, but some should be included in the final array of selected sites. Preference should also be given to sites that include areas with species-poor native plant communities owing to past disturbance, to avoid impacts to relict native vegetation. Selected sites collectively should exhibit variation in slope, aspect, fog sheltering, and wind exposure. A total of at least five sites should be selected. (Priority 2)

B 3.2. Secure selected reserve sites. Acquire sites through fee title purchase with conservation deed restrictions, or secure with conservation easements, or establish cooperative agreements for reintroduction sites that are municipally owned. Agreements and easements must cover the full scope of actions prescribed in restoration and recovery plans (Task B 3.3). (Priority 2)

B 3.3. Prepare restoration and reintroduction plans. Prepare restoration and reintroduction plans for all sites (conceptual general plan) and for specific sites (implementation plans), with emphasis on removal and suppression of regeneration of nonnative vegetation. At least three interior San Francisco sites should include plans for mixed transplanted populations of both San Franciscan manzanitas. At least 30 replicate transplants of Raven's manzanita should be assigned each site to allow for mortality. Plans should also include provisions for whatever removal of nonnative trees and shrubs is needed, eradication of invasive nonnative vegetation (and maintenance), protection of native vegetation, post-transplant care and maintenance, and reintroduction of associated native species of native grassland and coastal scrub communities, chosen to fit local substrate conditions, and derived from appropriate source populations. (Priority 2)

B 3.4. <u>Propagate stock for founder populations</u>. Propagate Raven's manzanita and Franciscan manzanita stock for transplanting, using clones of seed-propagated, genetically controlled plants. Priorities for genetic management of stock should be based on recommendations of a scientific peer review panel (see Task B 5.7, below). Part of the propagation process is to inoculate stock with mycorrhizae (fungi that associate with roots) derived from the remnant Presidio population. (Priority 2)

B 3.5. <u>Prepare reserve sites for reintroduction</u>. Prepare sites for reintroduction according to restoration and reintroduction plans by removing and suppressing regeneration of nonnative vegetation, but only after full completion of public outreach tasks. (Priority 2)

B 3.6. <u>Transplant and establish propagated founder plants</u>. Transplant and perform post-transplant maintenance and intensive monitoring using the same methods as for transplanted Presidio populations (Tasks B 2.5 to B 2.6). (Priority 2)

B 3.7. <u>Monitor transplants</u>. Monitor transplants and subsequent generations as for transplanted Presidio populations (Tasks B 1.2, B 2.6). If sites fail due to interference from excessive growth of native coastal scrub or grassland species, abandon the colony and replicate two additional reintroduction sites elsewhere on site or at new sites. (Priority 3)

B 4. Public outreach, education, and coordination.

Public outreach and education are particularly important for Raven's manzanita recovery because recovery depends on habitat restoration and reintroduction in urban reserves. Habitat restoration in San Francisco may involve removal of ornamental nonnative species. Additionally, reintroduction of endangered species may cause neighbors to have concerns about land use restrictions. Community support, including support of local governments, will be essential to implementation of recovery actions.

B 4.1. Promote native manzanita recovery broadly through education. Promote public education about native endemic manzanitas and their historic habitats to develop support for experimental restoration and reintroduction projects, as well as conservation of the remnant Presidio population. The U.S. Fish and Wildlife Service should collaborate with local natural history museums, nonprofit conservation organizations, Golden Gate National Recreation Area, Presidio Trust, local schools (including colleges and universities), and local botanical gardens to conduct educational programs (speakers, slide talks, field trips). (Priority 2)

B 4.2. Promote native manzanita recovery at the local community level. Well in advance of restoration activities – especially before removing any trees or conducting large-scale vegetation management or reintroduction tasks, conduct promotional public outreach to nearby neighborhoods through neighborhood associations, park associations, and local schools. It is also important to conduct broader public outreach programs using local media, formal public notice, and public meetings. Such outreach should be done in coordination with the Fish and Wildlife Service. Prepare scientifically accurate, written and oral accounts and graphic displays explaining the needs for species recovery, the needs for habitat restoration, and the time and spatial scales involved. Compile endorsements (written statements of official support) from government natural resource agencies and nonprofit conservation groups regarding restoration/reintroduction plans. Develop local support by using endorsements in information packages for the media, neighbors of prospective reserves, and other interested public citizens. Present accounts through public meetings, news media, and mailings. (Priority 2)

B 4.3. Promote native manzanita recovery through stewardship. Promote and provide Fish and Wildlife Service support (staff, funds) to public volunteer participation in monitoring and site stewardship (vegetation management) activities, in coordination with local nonprofit, volunteer-based conservation organizations, particularly ones with established volunteer site stewardship programs. (Priority 3)

B 4.4. Establish public demonstration gardens displaying cultivated Raven's manzanita clones. At or near potential sites of reintroduction, maintain cultivated clones of Raven's manzanita and selected associated species in neighborhood public demonstration gardens, in cooperation with local nonprofit urban horticulture and conservation organizations, in advance of restoration and reintroduction actions. Establish educational and stewardship programs for demonstration gardens to develop local community support for restoration and reintroduction tasks. (Priority 3)

B 5. Conduct research and development tasks supportive of recovery.

B 5.1. Search for "Raven's-like" Tamalpais manzanitas. Perform field surveys for individuals of Tamalpais manzanita (*Arctostaphylos montana*) from Marin County that are similar to Raven's manzanita, or individuals with at least multiple key characters (e.g., foliar, floral traits) overlapping with Raven's manzanita. Mark, map, collect, and propagate such specimens. Utilize propagated clones in studies of taxonomic relationships, or, if needed, for introgressive breeding. (Priority 2)

B 5.2. Investigate seed production and propagation of Raven's manzanita. Study seed production of artificially controlled self-pollinated Raven's manzanita. Determine whether viable seed can be produced through self-pollination. Compare with seed production of self-pollinated and outcrossed manzanitas (*Arctostaphylos montana*, *A. franciscana*, local *A. uva-ursi* [San Bruno, Point Reyes populations], and Monterey *A. hookeri* subspecies). Cultivate, label, and propagate all progeny, retaining pedigrees of each. Develop more reliable, rapid, and efficient techniques of clonal propagation of seed-propagated plants. (Priority 2)

B 5.3. Investigate taxonomic status and relationships of Raven's manzanita. Study in greater depth the systematic (including genetic) relationships between Raven's manzanita and other similar manzanita taxa of the central California coast region (e.g., *Arctostaphylos franciscana*, *A. montana*, *A. pungens*, *A. hookeri*, and *A. uva-ursi*, or other allied taxa). Molecular genetic analysis of a wider range of taxa in the genus, morphometric comparisons, studies of population variability, and synthesis of artificial hybrids should be addressed in research. (Priority 2)

B 5.4. Investigate substrate and plant interactions with Raven's manzanita. Study physiological ecology of substrate conditions (particularly variable mafic and ultramafic soil conditions) on growth, competition, and reproduction of endemic San Francisco manzanita subspecies and dominant associated native and nonnative species. Study potential effects of serpentine substrate on biotic interactions such as herbivory, pathogen resistance, and mycorrhizal function. (Priority 2)

B 5.5. Investigate reproductive ecology of Raven's manzanita. Study reproductive ecology of the remnant Presidio population (pollination, seed set, seed dispersal, and seed germination and establishment), and perform controlled experiments on germination and seedling growth responses of cultivated seed to relevant environmental and biotic factors that can be managed (e.g., fire, temperature, microbes, gut passage, etc.). (Priority 2)

B 5.6. Investigate practical specific nonnative vegetation control techniques. Study, develop, and refine effective and practical techniques of controlling or eradicating invasive nonnative plants on steep, rocky slopes in local urban settings, and on serpentine. (Priority 1)

B 5.7. Assemble a scientific review panel to evaluate and recommend a genetic management program for Raven's manzanita. An expert scientific peer review panel should evaluate the appropriateness and need for a breeding program for Raven's manzanita. The Fish and Wildlife Service, National Park Service (Golden Gate National Recreation Area), and the scientific panel should collaboratively develop a genetic management plan. The plan should describe a breeding program and recommendations on the use of newly bred Raven's manzanita plants in reintroduction. The panel should include experts in manzanita biology, plant conservation genetics, plant breeding, and plant propagation. (Priority 2)

B 6. <u>Undertake offsite conservation measures</u>.

B 6.1. <u>Collect and store seed of Raven's manzanita</u>. If self-pollinated Raven's manzanita seed are produced in the Presidio, approximately one third should be collected for long-term storage, and be deposited at a botanical garden certified by the Center for Plant Conservation. Additional seed should be stored by the Golden Gate National Recreation Area and local botanical gardens approved by the Fish and Wildlife Service. One third of harvested seed should also be collected for testing for hybridity, and propagation in support of experimental reintroduction if seed are not hybrid (see Task B 3.2). (Priority 3)

B 6.2. <u>Cultivate more Raven's manzanita in botanical gardens</u>. Raven's manzanita and Franciscan manzanita should be maintained in propagation and in plantings at local botanical gardens approved by the Fish and Wildlife Service. Educational signs explaining Raven's manzanita's endangered status, rarity and endemism, taxonomic status, and history of decline, should accompany plantings. Cultivated specimens rather than outplanted or wild populations should be used to supply herbarium and research material. (Priority 3)

B 6.3. <u>Promote and appropriate educational and outreach use of Raven's manzanita</u>. Cultivation of Raven's manzanita for educational purposes in San Francisco outside of botanical gardens should be encouraged where it would be useful in: (1) increasing public support and appreciation of this species; (2) encouraging volunteer participation in the stewardship of reintroduction sites; and (3) reassuring neighbors of potential reintroduction sites that the presence of this endangered plant species would not interfere with reasonable enjoyment of public lands where it is reintroduced. Local sponsors of demonstration plantings must comply any requirements for approvals by landowners. Qualified local native plant propagators should be permitted by the Fish and

Wildlife Service to propagate Raven's manzanita from Federal land at the Presidio, using stock from daughter clones, not the single original plant. It may be appropriate for such propagation permits to include stipulations about the disposition of propagated material. Demonstration plantings should be coordinated with local nonprofit conservation and horticultural organizations. (Priority 3)

VI. IMPLEMENTATION SCHEDULE

The implementation schedule that follows outlines actions and estimated costs for this recovery plan. It is a guide for meeting the objectives discussed in Chapter IV of this recovery plan. This schedule describes and prioritizes tasks, provides an estimated time table for performance of tasks, indicates the responsible agencies, and estimates costs of performing tasks. These actions when accomplished should further the recovery and conservation of the covered species.

<u>Key to Acronyms used in the Implementation Schedule</u>

Definition of task priorities:

Priority 1 – An action that must be taken to prevent extinction or prevent the species from declining irreversibly in the foreseeable future.

Priority 2 – An action that must be taken to prevent a significant decline in species population or habitat quality, or some other significant negative impact short of extinction.

Priority 3 – All other actions necessary to meet recovery or conservation objectives.

Definition of task durations:

Continual – A task that will be implemented on a routine basis once begun.

Ongoing – A task that is currently being implemented and will continue until action is no longer necessary.

Unknown – Either task duration or associated costs are not known at this time.

Abbreviations:

TBD	To be determined

Responsible parties:

CDFG	California Department of Fish and Game
DC	City of Daly City
GGNRA	Golden Gate National Recreation Area, National Park Service
OWN	Private landowners or parties
PC	Private consultant (contractor)
PNP	Private nonprofit organizations (local conservation, horticultural organizations)
PT	Presidio Trust
SF	City of San Francisco Department of Parks and Recreation
USFWS	U.S. Fish and Wildlife Service
UNIV	undetermined university research laboratories

Note: The first party or agency listed in the "responsible parties" column is the lead party denoted with (*).

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year					Comments/Notes
					Total ‡	1	2	3	4	
1	A 1.1.1.1	Modify the Presidio Vegetation Management Plan to prescribe maintenance and enhancement activities consistent with this recovery plan for San Francisco lessingia sites at the Presidio.	1 year	*GGNRA USFWS PT, CDFG	1	1	0	0	0	assume GGNRA staff preparation in coordination with USFWS, CDFG
1	A 1.1.1.2	Delineate and permanently dedicate Golden Gate National Recreation Area and Presidio Trust lands for recovery of San Francisco lessingia.	3 years	*GGNRA USFWS PT, CDFG	3	2	0.5	0.5	0	
1	A 1.1.1.3	Develop and implement site-specific management and monitoring plans for Presidio populations of San Francisco lessingia.	continual	*GGNRA USFWS PT, CDFG	30	1	1	1	1	
1	A 1.1.1.4	Commit resources to implement vegetation management plans affecting San Francisco lessingia at the Presidio.	continual	*GGNRA USFWS PT, CDFG	TBD					combination of agency and volunteer participation in maintenance and monitoring
1	A 1.1.3	Establish permanent and seasonal staff dedicated to lessingia vegetation management.	continual	*GGNRA PT	7 per yr (210)	7	7	7	7	salary, equipment, materials
1	A 1.2.1	Establish protection of Daly City population of San Francisco lessingia under existing ownership.	2 years or less	*USFWS, CDFG DC	1	1	0	0	0	voluntary cooperative agreement

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Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year					Comments/Notes
					Total ‡	1	2	3	4	
1	A 1.2.2	Acquire Daly City parcels within proposed San Francisco lessingia reserve.	2 years or less	*USFWS, CDFG, PNP, DC, OWN	150	0	150	0	0	uncertain appraisal and acquisition cost
1	A 2.1	Prepare plans for habitat restoration and augmentation or reintroduction of San Francisco lessingia populations.	4 years	*USFWS, CDFG GGNRA, PT, PNP, PC	25	10	5	5	5	includes topographic surveys, engineering designs, field sampling
1	A 2.2.1	Expand population and restore habitat above Lobos Dunes site.	5 years	*GGNRA USFWS PT, CDFG	24	0	0	20	1	requires prior planning of Task A 2.1
1	A 2.2.2	Expand populations and restore habitat from Lobos Dunes to Baker Beach Dunes.	5 years	*GGNRA USFWS PT, CDFG	40	0	0	20	5	requires prior planning of Task A 2.1
1	B 1.1	Control nonnative vegetation at the Presidio World War II Memorial Raven's manzanita site.	continual	*GGNRA	0.5 per yr (15)	0.5	0.5	0.5	0.5	
1	B 2.2	Control nonnative vegetation at Presidio transplant sites of Raven's manzanita.	continual	*GGNRA	0.5 per yr (15)	0.5	0.5	0.5	0.5	
1	B 5.6	Investigate practical specific nonnative vegetation control techniques at Raven's manzanita sites.	3 years	*USFWS, CDFG GGNRA, UNIV	6	2	2	2	0	
		Total estimated costs for priority 1 tasks			**520**	**15**	**161.5**	**51.5**	**15**	

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year					Comments/Notes
					Total ‡	1	2	3	4	
2	A 1.1.2	Monitor all Presidio populations of San Francisco lessingia.	continual	*GGNRA	TBD c. 3 per yr (90)	3	3	3	3	
2	A 1.2.3	Establish a land manager and endowment fund for management of the Daly City San Francisco lessingia reserve.	2 years or less	*USFWS, CDFG, DC, PNP	75	0	0	75	0	permanent endowment as one-time cost
2	A 1.2.4	Prepare and implement a long-term management and restoration plan for Daly City San Francisco lessingia reserve.	3 years	*USFWS, CDFG DC, PNP, PC	20	0	10	5	5	management cost under endowment Task A 1.2.3; restoration costs included here
2	A 2.1	Prepare plans for habitat restoration and augmentation or reintroduction of San Francisco lessingia populations.	4 years	*USFWS, CDFG GGNRA, PT, PNP, PC	25	10	5	5	5	includes topographic surveys, engineering designs, field sampling
2	A 2.2.3	Expand San Francisco lessingia populations and restore habitat above Lobos Dune Reserve through Wherry Housing Area, Presidio.	20 years	*PT, GGNRA, USFWS, CDFG	200	0	0	0	0	will not commence until after year 4; demolition costs derive from PT lease revenues not included in cost estimate
2	A 2.2.4	Expand San Francisco lessingia populations and restore habitat behind Marine Hospital, Presidio.	4 years	*PT, GGNRA, USFWS, CDFG	75	1	4	65	5	

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year Total ‡	1	2	3	4	Comments/Notes
2	A 2.2.5	Expand San Francisco lessingia populations and restore habitat within the Daly City Reserve.	3 years	*USFWS, CDFG, DC, PC	(20)	0	20	0	0	costs covered under Task A 1.2.4
2	A 2.2.6	Restore habitat and reintroduce San Francisco lessingia to dunes at Fort Funston/Lake Merced reserve for San Francisco lessingia.	5 years	*GGNRA, USFWS, CDFG	205	5	50	50	50	incremental expansion
2	A 2.3	Reintroduce beach layia to Fort Funston/Lake Merced dunes.	4 years	*GGNRA, USFWS, CDFG	3	1	1	0.5	0.5	duration may vary depending on annual rainfall variation
2	A 2.4.1	Acquire Hawk Hill dune remnant.	1 year	*USFWS, CDFG, SF, PNP, OWN	150	150	0	0	0	cost includes endowment for management
2	A 2.4.2	Acquire sand slopes near Sutro Heights.	2 years	*SF, OWN, GGNRA, USFWS, CDFG	150	5	145	0	0	uncertain parcel boundaries, acquisition cost, seller willingness
2	A 2.4.3	Control or eradicate invasive nonnative vegetation within satellite reserves.	continual	*GGNRA, PNP, USFWS, SF	150	5	5	5	5	cost in excess of acquisition/ endowment of OWN sites
2	A 2.4.4	Establish San Francisco lessingia in satellite reserves.	5 years	*USFWS, CDFG, GGNRA, SF, PNP	30	5	10	5	5	cost in excess of acquisition/endowment of OWN sites

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year					Comments/Notes
					Total ‡	1	2	3	4	
2	A 3.1	Prepare information presentations for public outreach (San Francisco lessingia).	5 + years	*USFWS, CDFG, GGNRA, PT, SF, PNP	TBD	–	–	–	–	
2	A 3.2	Conduct public outreach meetings prior to major recovery tasks for San Francisco lessingia.	5 + years	*USFWS, CDFG GGNRA, PT, SF, PNP	TBD	–	–	–	–	
2	A 3.3	Publicize and promote restoration sites for San Francisco lessingia in advance of modifications.	5 + years	*USFWS, CDFG, GGNRA, PT, SF, PNP	c. 1 per yr (5)	1	1	1	1	
2	A 3.4	Publicize effects of San Francisco lessingia projects on scenic views and recreational use of GGNRA/Presidio.	5 + years	*USFWS, CDFG, GGNRA, PT, SF, PNP	c. 3 per yr (15)	3	3	3	3	
2	A 4.2	Study rates and modes of recolonization by invasive nonnative plants and their control.	5+ years	*USFWS, CDFG, GGNRA, UNIV	5	2	1	1	0.5	requires long-term monitoring
2	A 4.4	Experimentally investigate rotational trail closure/temporary pedestrian exclosure as a management and conservation method for San Francisco lessingia.	5+ years	*USFWS, CDFG, GGNRA, UNIV	3.5	1	1	0.5	0.5	requires long-term monitoring
2	A 4.5	Conduct field experiments on restoring and managing dune topography conservation of San Francisco lessingia.	5+ years	*USFWS, CDFG, GGNRA, UNIV	7.5	5	1	0.5	0.5	requires long-term monitoring

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year					Comments/Notes
					Total ‡	1	2	3	4	
2	A 4.7	Study effects of substrate conditions on growth and reproduction of San Francisco lessingia.	3 years	*USFWS, CDFG, GGNRA, UNIV	5	2	2	1	0	
2	B 1.2	Monitor growth, reproduction, and clone size of Raven's manzanita at the World War II Memorial manzanita site.	continual	*GGNRA	ca. 0.5 per yr (15)	0.5	0.5	0.5	0.5	
2	B 1.3	Manage native vegetation around War Memorial Raven's manzanita site.	continual	*GGNRA	ca. 0.3 per yr (9)	0.3	0.3	0.3	0.3	assumes consistent minimal maintenance
2	B 2.1	Monitor growth and clone size of established Raven's manzanita transplants in the Presidio.	continual	*GGNRA	up to 0.7 per yr (21)	0.7	0.7	0.7	0.7	
2	B 2.3	Survey and select additional serpentine outcrop sites within the Presidio for reintroduction of Raven's manzanita.	2 years	*USFWS, CDFG, GGNRA, PT	1	0.5	0.5	0	0	part of 10 year program
2	B 2.4	Prepare sites selected for transplantation of Raven's manzanita in the Presidio.	TBD	*USFWS, CDFG, GGNRA, PT	TBD	–	–	–	–	part of 10 year program
2	B 2.5	Transplant replicated clones of Raven's manzanita to selected sites in the Presidio.	3 years	*USFWS, CDFG, GGNRA, PT	3	1	1	1	0	part of 10 year program

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year Total ‡	1	2	3	4	Comments/Notes
2	B 2.6	Monitor transplanted Presidio clones.	7 years	*USFWS, CDFG, GGNRA	7	0	0	0	1	part of 10 year program; later becomes part of Task A 2.1
2	B 3.1	Evaluate and select candidate reserves for reintroduced Raven's manzanita outside the Presidio in San Francisco.	1 year	*USFWS, CDFG, PNP, SF, OWN	1	1	0	0	0	
2	B 3.2	Acquire selected Raven's manzanita reserves outside the Presidio in San Francisco.	TBD (3 years?)	*USFWS, CDFG, PNP, SF, OWN	TBD	–	–	–	–	cost depends on landowner willingness to develop easements
2	B 3.3	Prepare restoration and reintroduction plans for Raven's manzanita reserves outside the Presidio in San Francisco.	2 years	*USFWS, CDFG, SF, PNP, PC, UNIV	5	0	2	3	0	
2	B 3.4	Propagate native manzanita stock from seed.	5 years	*USFWS, CDFG, UNIV, PNP	10	2	2	2	2	cost depends on unpredictable results of plant breeding
2	B 3.5	Prepare new San Francisco sites for reintroduction of native manzanitas.	2 years	*USFWS, CDFG, PNP, PC, SF	20	0	0	0	10	cost may vary with potential tree removal
2	B 3.6	Transplant and establish propagated native founder manzanita populations.	3 years	*USFWS, CDFG, PNP, PC, SF	1	0	0	0	0	will occur after restoration
2	B 4.1	Promote native manzanita recovery through education.	5+ years	*USFWS, CDFG, PNP, SF, UNIV	5	1	1	1	1	cost may depend on integration with existing programs

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year					Comments/Notes
					Total ‡	1	2	3	4	
2	B 4.2	Promote native manzanita recovery at the local community level.	5+ years	*USFWS, CDFG, PNP, SF, UNIV	8	1	1	2	2	
2	B 5.1	Search for "Raven's-like" Tamalpais manzanitas (*Arctostaphylos montana*).	3(+) years	*USFWS, CDFG, UNIV	1	0.2	0.2	0.2	0.2	includes propagation, mapping costs; search time uncertain
2	B 5.2	Investigate seed production and propagation of Raven's manzanita.	4 years	*UNIV, USFWS, CDFG	6	2	2	1	1	may extend beyond 4 years depending on results
2	B 5.3	Investigate taxonomic status and relationships of Raven's manzanita.	3 years	*UNIV, USFWS, CDFG	8	4	3	1	0	
2	B 5.4	Investigate substrate and plant interactions with Raven's manzanita.	5 years	*UNIV, USFWS, CDFG	9	3	2	2	1	
2	B 5.5	Investigate reproductive ecology of Raven's manzanita.	3 years	*UNIV, USFWS, CDFG	5	2	2	1	0	
2	B 5.7	Assemble a scientific review panel to evaluate and recommend a genetic management plan for Raven's manzanita.	1 year	*USFWS, CDFG, UNIV, PC, GGNRA	2	2	0	0	0	
		Total estimated costs for priority 2 tasks			**1,146**	**220.2**	**280.2**	**236.2**	**103.7**	
3	A 3.5	Actively support public volunteer participation in monitoring and site stewardship of San Francisco lessingia reserves.	TBD	*USFWS, CDFG, PNP, GGNRA, SF	c. 1 per yr (30)	1	1	1	1	

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year					Comments/Notes
					Total ‡	1	2	3	4	
3	A 4.1	Study variation in ecological and genetic characteristics of San Francisco lessingia.	2 years	*USFWS, CDFG, GGNRA, UNIV, PC	5	0	2	3	0	
3	A 4.3	Study the pollination ecology of San Francisco lessingia.	2 years	*USFWS, CDFG, GGNRA, UNIV	2	1	1	0	0	
3	A 4.6	Study seed dispersal and seed bank ecology of San Francisco lessingia.	5+ years	*USFWS, CDFG, GGNRA, UNIV	5	0	2	2	0.5	requires long-term monitoring
3	A 4.8	Clarify taxonomic relationships between San Francisco lessingia and allied species.	4 years	*USFWS, CDFG, GGNRA, UNIV, DC, OWN	5	2	1	1	1	
3	A 5.1	Establish cultivated populations of San Francisco lessingia at botanical gardens.	ongoing	*USFWS, CDFG, UNIV, PNP	1	0.5	0.5	0	0	
3	A 5.2	Maintain stored seed bank to ensure survival of San Francisco lessingia.	ongoing	*UNIV, PNP, USFWS	3	0.1	0.1	0.1	0.1	will require periodic recollection to ensure viability
3	B 2.7	Identify and protect known and potential serpentine outcrop sites in the Presidio.	3 years	*GGNRA, PT, PC	5	1	3	1	0	

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year					Comments/Notes
					Total ‡	1	2	3	4	
3	B 2.8	Reintroduce associated serpentine plant species to serpentine outcrop sites in the Presidio.	ongoing	*GGNRA, PT, SF, PNP	TBD	–	–	–	–	costs may depend on availability of stock populations and ease of propagation establishment
3	B 3.7	Monitor transplants of Raven's manzanita in San Francisco outside the Presidio.	ongoing	*UNIV, PC, PNP, USFWS, CDFG	TBD	–	–	–	–	ongoing
3	B 4.3	Promote native manzanita recovery through stewardship.	continual	*USFWS, CDFG, PNP, SF,	TBD	–	–	–	–	
3	B 4.4	Establish public demonstration gardens displaying cultivated Raven's manzanita clones.	5 years	*PNP, USFWS, CDFG, SF	1.25	0.25	0.25	0.25	0.25	maintain through local stewardship with small endowment
3	B 6.1	Collect and store seed of Raven's manzanita.	ongoing	*GGNRA, UNIV, PNP	3	0.1	0.1	0.1	0.1	will require periodic recollection to ensure viability
3	B 6.2	Cultivate Raven's manzanita in botanical gardens.	ongoing	*PNP, UNIV, USFWS, CDFG	1	1	0	0	0	add to existing cultivated population; include new seedlings
3	B 6.3	Promote and authorize appropriate educational and outreach use of Raven's manzanita.	ongoing	*USFWS, CDFG, PNP, SF	3	0.1	0.1	0.1	0.1	
		Total estimated costs for priority 3 tasks			**64.25**	**7.05**	**11.05**	**8.55**	**3.05**	

Implementation Schedule for Northern San Francisco Peninsula Coastal Plants Recovery Plan

Task Priority	Task Number	Task Description †	Task Duration	Responsible Parties	Cost Estimate (in $10,000 units) by fiscal year					Comments/Notes
					Total ‡	1	2	3	4	
Total estimated costs					**1,730.25**	**242.25**	**452.75**	**296.25**	**121.75**	

† Task Description: Please see Stepdown Narrative (Chapter V) for a full list of species included in each task.

‡ For purposes of estimating total cost of implementing the recovery plan (see Executive Summary), continual tasks or tasks of undetermined duration with costs given on a per year basis are multiplied by 30 years, the minimum estimate of time to delisting of San Francisco lessingia and downlisting of Raven's manzanita. Tasks of a specified duration with costs given on a per year basis are multiplied by the duration of the task.

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VIII. APPENDICES

APPENDIX I
Native Vascular Plant Species of Coastal Dunes and Dune Slacks of the Northern San Francisco Peninsula

The following list of vascular plants recorded from the San Francisco dune system is compiled from Howell *et al*. (1958) Brandegee (1892), Thomas (1961), and recent field observations (P. Baye unpubl. data 1984-1999). Locations are cited from Howell *et al*. (1958) unless otherwise noted. Species included are either currently verified from dune habitats, or have been identified on “sandy soils” (older organic-stained, stabilized dune scrub or grassland) or “sandy flats” (dry dune slack, deflation plain) at locations known to include recent (Holocene) dune deposits, and are presumed to be dune localities. Some sandy soil locations near Lake Merced or Ocean View may be Colma formation sands rather than dune, however. Wetland plants collected from localities of historic dune slacks are included.

Nomenclature generally follows Hickman (1993), based on synonymy given in that volume or Munz (1959), unless infraspecific taxa are cited that are not recognized in Hickman (1993). Question marks (?) indicate some uncertainty of collection on dune substrates, or somewhat uncertain taxonomic status. Localities cited in Howell *et al*. (1958) named with “obligate” (high fidelity or frequency) dune species or multiple collections of dune species include Point Lobos, Lobos Creek, Presidio, Lone Mountain, “dunes, Sunset district”, Sunset Heights, Lake Merced, Golden Gate Park, Ocean beach, Baker Beach/above Baker Beach, and near Cliff House. Conventional common names are compiled primarily from Best *et al.* 1996 and Hickman 1993. Arbitrary English names are given in brackets [ ] when no conventional English name is known.

PTERIDOPHYTES
(Ferns and fern-like plants)

AZOLLACEAE

Azolla filiculoides Lam. AMERICAN WATER-FERN, MOSQUITO-FERN. “...among dunes in Sunset district...”. Localities undoubtedly refer to perennially ponded dune slacks.

EQUISETACEAE

Equisetum hyemale ssp. ***affine*** (*E. hyemale* “var. *elatum* (Engelm.) Morton”) GIANT SCOURING RUSH. “moist or wet places on coastal dunes...Lobos creek..Lake Merced”. Also occurs on sand slope with dune vegetation at Hillside Park, Daly City.

POLYPODIACEAE

Polypodium californicum Kaulfuss. CALIFORNIA POLYPODY FERN, CALIFORNIA SHIELD FERN. "...rarely sandy slopes of hills...above Bakers beach...Land's End...Lone Mountain....dunes south of Golden Gate Park...". Also rare on old stable dunes of a north-facing slope at Fort Funston.

Pteridium aquilinum (L.) Kuhn **var. *pubescens*** L. Underw. BRACKEN FERN. "widespread and rather common on dune hills...Presidio, Lone Mountain, Golden Gate Park, Sunset Heights". Common in stable dune grassland and scrub in San Francisco today.

ANGIOSPERMS (Anthophytes)

Flowering Plants

Dicots (Broadleaf flowering plants)

APIACEAE

Daucus pusillus Michaux RATTLESNAKE WEED. "brushy slopes and in open grassland...Sunset Heights...Lake Merced". Locally common in stable dunes of the Presidio, Sunset Heights, and Fort Funston.

? ***Oenanthe sarmentosa*** Presl. WATER CELERY. This species likely occurred in some wet dune slacks of the Sunset and Richmond districts; it was recorded in streams and lakes adjacent to or within dune systems, such as Lobos Creek and Lake Merced.

ASTERACEAE

Achillea millefolium L. (*A. borealis* Bongard ssp. *arenicola* (Heller) Keck) YARROW. "..common in...sandy soil in natural areas...sand hills, San Francisco...Presidio...Lone Mt...dunes, Sunset district...Lake Merced....". Still locally common.

Agoseris apargioides (Less.) E. Greene var. ***eastwoodiae*** COAST DANDELION. "Common on dunes, grassy hills...sand hills near San Francisco...Presidio...Point Lobos...Lone Mountain....dunes, Sunset District....". Still locally common.

Ambrosia chamissonis (Less.) E. Greene. (*Franseria chamissonis* Lessing; varieties *bipinnatisecta* and *chamissonis* not recognized; both forms and intermediates occur in San Francisco) BEACH-BUR. "Sandy flats, occasionally in clayey soil near the shore: Presidio; Lone Mountain...Golden Gate Park; dunes, Sunset district...Lake Merced...Fort Mason....near Islais Creek.". A dominant species of foredunes, mobile dunes, and early phases of stable dunes. Also frequent at Ocean Beach.

Anaphalis margaritacea (L.) Benth. & Hook. PEARLY EVERLASTING. "brushy slopes....dunes, Sunset district...Lone Mountain....Presidio..."

Artemisia pycnocephala De Candolle DUNE SAGEWORT, DUNE SAGE. "Dunes and sandy flats: Lobos Creek...Bakers Beach..Laurel Hill Cemetery...Lake Merced." Also occurs at Sunset Heights. San Francisco is the type locality.

Baccharis pilularis DC. COYOTE BRUSH. "Dune flats and open hillsides...Presidio...Point Lobos...Lone Mountain....dunes, Sunset district.... Lake Merced...". Still a dominant species of dune scrub locally.

Cirsium occidentale (Nutt.) Jepson var. ***occidentale***. COBWEBBY THISTLE, WESTERN THISTLE. "Common on sandy slopes or dune flats, rarely in rocky soil...above Bakers Beach...Golden Gate Park...Sunset Heights....Ocean View....Lake Merced...". Persists at Baker Beach, Fort Funston dunes. Funston plants are notably short and basally branched, possibly tending towards var. *compactum*, but are distinctly cauline.

Cirsium occidentale (Nutt.) Jepson var. ***compactum*** Hoover COMPACT COBWEBBY THISTLE. Taxonomic affinity of San Francisco specimens is questionable. Apparently extirpated in San Francisco (Skinner & Pavlick 1994, Wood 1996), probably always rare here if referable to this taxon. Formerly not distinguished from var. *occidentale*.

Ericameria ericoides (Less.) Jepson (*Haplopappus ericoides* (Less.) Hook.& Arn.) FALSE HEATHER. "common in low shrub of dunes and sandy hills: Presidio...Lands End...Lone Mountain....Golden Gate Park....dunes, Sunset district...Lake Merced....Chamisso collected the type in San Francisco....". Persists at Sunset Heights, Baker Beach, Presidio, Fort Funston ("Lake Merced") localities.

Erigeron glaucus Ker-Gawler SEASIDE DAISY. "Coastal bluffs, sandy flats, and rocky hills: Presidio....west of Lake Merced [Fort Funston]...". Found locally primarily on older stable dunes.

Erigeron foliosus Nutt. var. ***franciscensis*** G. Nesom. LEAFY DAISY. "Grassy slopes near brush...not common; Point Lobos...Lake Merced...". Recorded generally from habitats including dune grassland (Hickman 1993). Not reported recently from local dunes; possibly extirpated.

Eriophyllum staechadifolium Lascaga (*E. s*. var. *artemisiaefolium* (Lessing) Macbride) LIZARD-TAIL, SEASIDE WOOLY-SUNFLOWER. "Bluffs and brushy hills on or near the coast: ....Golden Gate Park...Lake Merced...". Occasional on older dunes today at Fort Funston, Baker Beach.

Gnaphalium stramineum Kunth (*Gnaphalium chilense* Sprengel) CUDWEED.   "Common and widespread in sandy and clayey soils in grassland or brush: Presidio...Golden Gate Park...dunes, Sunset district...". Occasional to locally common in San Francisco dunes.

Gnaphalium purpureum L. CUDWEED. "Rather common in open grassy places, rarely ruderal: Presidio...Lone Mountain...Golden Gate Park...Lake Merced...". Occasional to locally common in older San Francisco dunes.

Grindelia hirsutula Hook. & Arn. var. ***maritima*** (E. Greene) M.A. Lane (*G. maritima* (Greene) Steyermark) SAN FRANCISCO GUMPLANT. "Coastal bluffs, sandy flats, and open or brushy slopes...Presidio....Lake Merced...probably the San Francisco Grindelia collected by Chamisso in 1816...." Occurs at Fort Funston on wind-reworked Merced formation sands, possibly planted.

Grindelia stricta DC. var. ***platyphylla*** (E. Greene) M. A. Lane (*G. arenicola* Steyermark var. *pachyphylla* Steyermark) [BROADLEAF GUMPLANT] . "A collection made by L.S. Rose in 1930 is cited from San Francisco by Steyermark (Ann. Mo. Bot. Gard. 21:596, -1934)." This species, regionally found in dunes at Point Reyes, was not cited for the San Francisco flora by Brandegee (1892), and probably was rare here. Common on bluffs of San Mateo coast and Point Reyes dunes and bluffs. Now extirpated in San Francisco.

Lasthenia glabrata Lindley ssp. ***glabrata*** SMOOTH GOLDFIELDS. "Wet valley lands ....reported from the western part of the city across to Visitacion Valley". "Wet valleys" in the western part of the city are likely to have included dune slacks since the western part of the city was almost entirely covered by the San Francisco dune sheet.

Lasthenia minor (*Baeria minor* (DC.) Ferris) GOLDFIELDS. "Moist places in sandy and clayey soil...Lake Merced...Presidio golf course...". Though not specifically cited from San Francisco dunes, "moist places in sandy...soil" at Lake Merced and the Presidio golf course" are likely former dune occurrences. This species is locally common on older dunes of Point Reyes and Dillon Beach, Marin county, and would have been a likely species of dune slacks and old dunes in San Francisco.

Layia carnosa (Nutt.) Torrey & A. Gray BEACH LAYIA. Thomas (1961) cites this species as "occ. on coastal sand dunes, known so far locally only from San Francisco". No collections are cited. Not reported in Howell *et al*. 1958, or in California collections of California Academy of Sciences, University of California, or Jepson Herbarium. Probably occurred at most as a local small population since it was not recorded by Brandegee (1892) or Howell *et al*. 1958. Now extirpated; nearest population is at Point Reyes, in dunes near Abbotts Lagoon.

Layia platyglossa (Fischer & C. Meyer) A. Gray TIDY TIPS. "Common in grassy places...San Francisco sand hills...Presidio....Point Lobos....Sunset Heights...Lake Merced".

Lessingia germanorum Cham. SAN FRANCISCO LESSINGIA. "Sandy flats and dune hills: San Francisco...Presidio...Lone Mountain...Lake Merced....The original collection, on which the genus and species were based, was made by Chamisso in San Francisco in 1816...". (See text and Table 1 of this recovery plan for detailed historic locality information).

Lessingia filaginifolia (Hook. & Arn.) M.A. Lane var. ***californica*** (*Corethrogyne californica* De Candolle) CALIFORNIA-ASTER. "Reported by Greene...[1894]...from sandy hills, Lake Merced." Presumed extirpated here on dunes.

Microseris bigelovii (A. Gray) Schultz-Bip. MICROSERIS. "Widespread and rather common on sandy, rocky, or clayey soils of open flats and slopes: ...Presidio...Lone Mountain.. ".

Senecio aronicoides DC. RAGWORT. "Grassy or brushy slopes, generally in partial shade: above Bakers Beach, Presidio...Sunset Heights...Lake Merced...". Current status on local dunes uncertain; not recently reported.

Solidago spathulata DC. GOLDENROD. "Open slopes and flats in rocky, clayey, or sandy soil: ....Lone Mountain...Sunset Heights....Lake Merced....collected....by Chamisso...". Remnant natural dune populations today mostly in Sunset Heights; scarce in the Presidio dunes.

Tanacetum camphoratum Less. DUNE TANSY. " Forming colonies on sandy flats and dunes: San Francisco sand hills...Point Lobos....dunes, Sunset District...Ocean beach...type collected in San Francisco by Chamisso.". Remnant natural dune populations in the Presidio, dunes near Cliff House (above Balboa at Great Highway), Sunset Heights, Fort Funston. Nearest population is Dillon Beach, Marin County.

Uropappus lindleyi (DC.) Nutt. (*Microseris linearifolia* (DC.) Schultz-Bip.) SILVER-PUFFS. "Grassy or brushy slopes....Lobos Creek, Presidio...dunes, Sunset district....Lake Merced...". Common in grassland and ruderal habitats as well as on dunes.

BORAGINACEAE

Amsinckia spectabilis Fischer & C. Meyer COAST FIDDLENECK. "common on dunes and on sandy and grassy flats: above Bakers Beach...Point Lobos..Lone Mountain...dunes, Sunset district...Lake Merced". Persists in Presidio dunes.

(?) ***Cryptantha clevelandii*** E. Greene *(C. hispidissima* E. Greene, *C. c.* var. *florosa.* I.M. Johnston) [CLEVELAND'S POPCORNFLOWER]. "sandy slopes and flats...San Francisco....Lake Merced". May be locally extirpated.

Cryptantha leiocarpa (Fischer & Meyer) E. Greene DUNE POPCORNFLOWER. "on dunes and sandy flats....near Bakers Beach....Presidio...Golden Gate Park...". Persists at historic localities and restored dunes nearby.

? ***Nemophila pedunculata*** Douglas ex Benth. [STALKED NEMOPHILA]. "...open grassland or under brush....Point Lobos...Lone Mountain...Lake Merced". Probably extirpated in San Francisco dunes. Occurs in stable dunes in Monterey Bay, Morro Bay.

? ***Plagiobothrys*** spp. *(P. chorisianus (Allocarya chorisiana*), *P. reticulatus var. rossorianum (Allocarya diffusa)*, possibly other spp., like *P. stipitata*, may have occurred locally in dune slacks. POPCORNFLOWERS. They are cited from historic localities that included dunes and possibly dune slacks (Lake Merced, near Lobos Creek, Golden Gate Park. [uncertain. cited as "locally common in moist places", including Lobos Creek and Golden Gate Park. Possibly present in dune slacks; *Plagiobothrys* spp. (within former genus *Allocarya)* are rarely found at Point Reyes dune slacks, and are locally abundant at wet young slacks at Manchester Beach dunes near stream mouths.

BRASSICACEAE

Erysimum franciscanum Rossbach FRANCISCAN WALLFLOWER. "...dune hills and ocean bluffs in the western part of the city...sand hills near San Francisco...above Baker Beach...Lone Mountain...Sunset Heights...". Persists at Baker Beach, Presidio, Fort Funston and Sunset Heights dunes.

CARYOPHYLLACEAE

Minuartina californica (A. Gray) Mattf. *(Arenaria californica* (A. Gray) Brewer) CALIFORNIA SANDWORT. "sandy places and grassland.... 'meadows among sand dunes south of the Park', acc. Brandegee.".

Arenaria paludicola Robinson MARSH SANDWORT. "Swamps....Fort Point." Long extinct; last reported by Hans Behr in the 1850's from the Presidio Swamp, located behind or within a barrier beach and dune complex, now Crissy Field.

Cardionema ramossisimum (J.A. Weinm.) Nelson & J. MacBr.) SAND MAT. "dune hills...Bakers Beach...dunes near Cliff House.. dunes, Sunset district....". Persists at these localities; also at Sunset Heights, Fort Funston.

Cerastium arvense L. FIELD CHICKWEED. "Sunset Heights...Lake Merced". Persists at Sunset Heights dune remnants.

(?) ***Sagina maxima*** A. Gray var. ***crassicaulis*** (S. Watson) G. Crow *(S. crassicaulis)* BIG PEARLWORT. "moist bluffs and flats just above the ocean: Bakers Beach...Point Lobos". Presumed extirpated in dunes and bluffs in San Francisco. This species is primarily found at sandstone bluffs, but occurs in dune slacks at Point. Reyes; "flats just above the ocean" at Baker Beach probably refers to dune slacks. *S. occidentalis* also possibly occurred in dune slacks.

Silene verecunda S. Watson ssp. ***verecunda*** SAN FRANCISCO CAMPION. "above Bakers Beach...brushy dunes, Sunset district". San Francisco is the type locality. Persists at Baker Beach; reintroduced to Lobos dunes, Presidio.

Stellaria littoralis Torrey COAST STARWORT. "In wet sandy soil of maritime slopes: Lands end...". Extirpated in San Francisco. Locally abundant in dune slacks of Point Reyes and Brazil Beach (Tomales Bay mouth).

CHENOPODIACEAE

Chenopodium californicum (S. Watson) S. Watson. CALIFORNIA GOOSEFOOT. "Rare on brushy hillsides: coastal slopes, Presidio...sandy hollow east of Lake Merced...". Occasional in old, weathered stable dune soils, dune scrub of Monterey Bay, Morro Bay, and Point Reyes; collected by M. Chassez, Golden Gate National Parks Association in 1997, near Rob Hill, Presidio, on old stable dune soil.

Atriplex californica Moquin CALIFORNIA SALTBUSH. "...maritime species of bluffs and dune flats: Point Lobos...Fort Point according to Brandegee". Extirpated in "dune flats"; persists in bluffs at Point Lobos and west of Fort Point. Uncommon to rare on San Mateo coast bluffs; the nearest populations are in Pacifica.

Atriplex leucophylla (Moquin) D. Diedrich. BEACH SALTBUSH. "Sandy shores along bay and ocean". Still frequent some years at Ocean Beach, occasionally Crissy Field.

CONVOLVULACEAE

Calystegia soldanella (L.) R. Br. BEACH MORNING-GLORY "..sands near the shore of the Presidio" according to Brandegee. Extirpated in San Francisco, but reintroduced to Crissy Field (Presidio) in 1998 from Linda Mar (Pacifica) and Half Moon Bay.

CRASSULACEAE

Crassula connata (Ruiz Lopez & Pavon) A. Berger. (*Tillaea erecta* Hook. & Arn.) SAND PYGMY WEED. "sandy flats...near Baker Beach...Land's End...Lone Mountain...". Persists in dunes near Baker Beach.

Dudleya farinosa Abrams (*Escheveria farinosa* Lindley) COAST DUDLEYA. Occurs as locally frequent component of vegetation on old stable remnant dunes of Sunset Heights and Fort Funston. No dune collections are cited in Howell *et al*. 1958, who described only bluff and rocky outcrop habitats.

CUCURBITACEAE

Marah fabaceus (Naudin) E. Greene CALIFORNIA MAN-ROOT. "Common on dunes.....Lands End to Fort Point...near Lobos Creek...above Bakers Beach....dunes, Sunset district..." Persists in dunes near Baker Beach, Sunset Heights.

EUPHORBIACEAE

Croton californicus Muell. CALIFORNIA CROTON. "open sandy flats or sandy soil on brushy slopes...Presidio....Lobos Creek....above Bakers beach...Lone Mountain...Lake Merced.". Extirpated near Lake Merced (Fort Funston dunes) and Lone Mountain, but persists at Sunset Heights (Hawk Hill) and Presidio dune localities. San Francisco is the type locality and northern coastal range limit.

FABACEAE

Astragalus nuttallii (Torrey & A. Gray) J. Howell var. ***virgatus*** (A. Gray) Barneby. [NUTTALL'S MILKVETCH]. "Brushy places, usually on sandy soil: Presidio...Point Lobos...Ocean View...Lake Merced...". Likely occurred on sandy bluff (Merced, Colma sandstone) or Holocene dune soils. Occurs locally in restored dunes at Fort Funston (Lake Merced).

Lathyrus littoralis (Nutt.) Endl. BEACH PEA. "Dunes and ocean beach west of Lake Merced [Howell, Raven]". Brandegee (1892) indicated the same population south of the outlet of Lake Merced. California Native Plant Society, Yerba Buena Chapter, located a new population on graded sands within the water treatment facility at this locality, in 1998 (P. Holloran pers. comm. 1998).

(?) ***Lathyrus vestitus*** Nuttall var. ***vestitus*** (*L. v.* ssp. *bolanderi* Watson. HILLSIDE PEA. "...grassy and brush slopes: Near Baker Beach..Sunset Heights...Lake Merced...". Not currently reported from dune sand substrates.

Lotus heermanii (Durand & Hilgard) E. Greene var. ***orbicularis*** (A. Gray) Islay (*L. eriophorus* Greene, *Hosackia tomentosa* Brewer & Watson) WOOLLY LOTUS. "Sandy flats and slopes: dunes, Sunset district...Lake Merced...". Persists at least at one locality at Fort Funston.

Lotus humistratus E. Greene SHORT-PODDED LOTUS. " ...'common in the western part' [of the city]..." according to Brandegee (1892).

Lotus scoparius (Nuttall) Ottley DEERWEED, CALIFORNIA BROOM. "Sandy flats...Presidio...Point Lobos...Sunset Heights...dunes, Sunset district...Lake Merced..". Still abundant locally in dune scrub.

Lotus strigosus (Nuttall) E. Greene BISHOP'S LOTUS. "Sandy flats and bluffs: Lobos Creek...Lone Mountain. ...dunes, Sunset district...".

Lotus wrangelianus Fischer & C. Meyer (*L. subpinnatus* Lagasca misappl.) CHILE LOTUS. "sandy ...soil ....Presidio...Lone Mountain.".

Lupinus arboreus Sims. YELLOW LUPINE, BUSH LUPINE, TREE LUPINE. "Common and widespread in sandy or clayey soil, frequently growing in disturbed places: dunes, Sunset District Rubzoff...". Not recorded on dunes in earliest local surveys of woody vegetation by Bolander (1863). Actively planted for dune stabilization (McLaren 1924, Clary 1980). By late 1900's, Brandegee (1892) recorded *L. arboreus* as frequent in sands of western half of city. San Francisco is the probable source of seed that grew the type specimens. No blue ("var. *eximius*") types occur in San Francisco.

Lupinus bicolor Lindley MINIATURE LUPINE. "Widespread in sandy..soil...our commonest annual lupine...above Bakers Beach...Lone Mountain...dunes, Sunset district....". Now scarce in San Francisco; persists at Sunset Heights dune remnants and around Lobos Dunes.

Lupinus chamissonis Eschscholtz BLUE BEACH LUPINE, SILVER BEACH LUPINE, CHAMISSO'S LUPINE. "Sandy soil of dune hills and flats....: above Bakers Beach...Presidio...dunes, Sunset district..Lake Merced...". Type locality is San Francisco, in or near Presidio. Still locally abundant at most remnant dune sites other than Crissy Field.

Lupinus nanus Douglas ex Bentham. SKY LUPINE. "Hillsides and flats in sandy and clayey soil: sand hills near San Francisco...Presidio..Lone Mountain...Lake Merced...". Now scarce in dunes; spontaneous occurrences are doubtful.

Lupinus variicolor Steudel. [COAST LUPINE]. "Open grassland in sandy or clayey soil....". Occurs primarily on coastal bluffs. Current spontaneous dune localities uncertain.

(?) ***Trifolium macraei*** Hook. & Arn. CHILE CLOVER. "Sandy ....open hillsides and flats, rather common...Presidio..." Probably occurred in dune slacks, as at Dillon Beach, Marin County.

(?) ***Trifolium wildenovii*** Sprengel (*T. tridentatum* Lindley) TOMCAT CLOVER. "Widespread in open grassy places... Lone Mountain....Presidio...Sunset Heights...Lake Merced...".

(?) ***Trifolium wormskioldii*** Lehmann COW CLOVER. "wet meadows and hillside seepages... Presidio...Pt. Lobos...Lone Mountain....". Probably occurred in some moist dune slacks, as at Dillon Beach, Marin County.

FAGACEAE

Quercus agrifolia Nee COAST LIVE OAK. "...dune hills...Lobos Creek...Golden Gate Park...". Persists in old remnant dunes behind Marine Hospital and Lobos Creek banks, Presidio, and near the Fuchsia Dell, Golden Gate Park.

GENTIANACEAE

(?) ***Centaurium*** spp. CENTAURY. *Centaurium davyi* (Jepson) Abrams (possibly *C. trichanthum* Grisb.) Robinson) may be expected in dune slacks and old dune soils, as at Pt. Reyes, Marin County, and Tenmile dunes, Mendocino County. Howell *et al.* (1958) state that the identity of "*C. douglasii*" of Behr's San Francisco flora is uncertain. *C. davyi* occurs locally on coastal headland grassland with thin old dune soils at Pacifica. *C. muehlenbergii* occurs on clayey soils in southern San Francisco, but is not generally found on dunes.

(?) ***Cicendia quadrangularis*** (Lam.) Grisb. (*Microcala q.* (Lam.) Grisb.) AMERICAN MICROCALA. This species was reported by Brandegee from Presidio. It occurs in the Bay area in seasonal wetlands and vernal pools. It possibly occurred here in sparsely vegetated dune slacks, as at Tenmile Dunes, Mendocino County.

HYDROPHYLLACEAE

Phacelia californica Cham. CALIFORNIA PHACELIA. "...common....sandy soil..Sunset Heights...dunes, Sunset district...". Persists in relict old dunes at Sunset Heights. Otherwise found primarily on stony soils and bluffs. Occasional in old stable dunes of the central coast.

Phacelia ciliata Benth. GREAT VALLEY PHACELIA. "sandy flats...near Lone Mountain...". Probably an occasional or incidental species in local dunes. Current status in San Francisco dunes uncertain.

Phacelia distans Benth. COMMON PHACELIA, WILD HELIOTROPE. "common on sandy flats....Presidio....Point Lobos....Lone Mountain...dunes, Sunset district....". Still locally abundant in stable dunes and other plant communities.

LAMIACEAE

Monardella undulata Benth. WAVY-LEAVED MONARDELLA. "sandy flats at Lake Merced". It is not certain whether this locality was east (on Colma formation sand deposits) or west (on recent surface dunes) of Lake Merced. The species occurs primarily on dune sand in most of its range. The nearest population is at Point Reyes dunes.

Monardella villosa Benth. **ssp.** ***franciscana*** (Elmer) Jokerst FRANCISCAN COYOTE-MINT. "sandy slopes...more common in western part of the city: Lake Merced...". Not recently reported; may be extirpated locally in dunes.

Satureja douglasii (Benth.) Briq. YERBA BUENA. "brushy slopes...dunes, Sunset district". Occurs marginally in moist, shaded dune slopes.

MYRICACEAE

Myrica californica Cham. CALIFORNIA WAX-MYRTLE. "in wet and marshy places in gullies and on dunes....dunes, Sunset District". Occurs also in dune slacks of Marin, Sonoma, and Mendocino Counties. San Francisco is the type locality.

ONAGRACEAE

Clarkia davyi (Jepson) H. Lewis & M. Lewis DAVY'S CLARKIA. "Sandy flats along the coast: dunes, Sunset district...Lake Merced ...southernmost station for the species."

(?) ***Clarkia rubicunda*** Lindley (H. Lewis & M. Lewis) CLARKIA. "Locally common on grassy or brushy slopes and coastal bluffs...hills near Golden Gate Park." This species occurs on Pleistocene sand of Daly City, at San Bruno Mountain (McClintock *et al*. 1990), and Fort Funston.

Camissonia cheiranthifolia (Sprengel) Raim ssp. ***cheiranthifolia*** (*Oenothera cheiranthifolia* Hornemann) BEACH EVENING-PRIMROSE. "Common on sandy slopes and flats: above Bakers Beach...Richmond district...Lone Mountain...Golden Gate Park...dunes, Sunset district...Lake Merced...". Common in nearly all dune remnants with vegetation gaps. The subspecies *C.c*. ssp. *suffruticosa* was introduced to Crissy Field dunes in a seed mix from obtained from southern coastal California (Terri Thomas pers. comm. 1997), and has spread there and to Fort Funston (through transplantation), where it has apparently hybridized with native populations to form intermediates (petal sizes exceeding the range of native subspecies, coarser habit).

Camissonia contorta (Douglas) Raven (*Oenothera contorta* Douglas ex Hooker var. *strigulosa* (Fischer & Meyer) Munz, misapplied). [TWISTED EVENING-PRIMROSE]. Not distinguished from *C. strigulosa* (as *Oe. contorta* var. *strigulosa;* see below) in Howell *et al.* (1958). Status in San Francisco is unclear; typically found inland.

Camissonia micrantha (Sprengel) Raven (*Oenothera micrantha* Hornemann) [SMALL-FLOWERED EVENING-PRIMROSE] "Coastal bluffs, dunes, and sandy flats: above Bakers Beach....near Point Lobos..Golden Gate Park...Lake Merced...".

Camissonia strigulosa (Fischer & Meyer) Raven (*Oenothera contorta* Douglas ex Hooker var. strigulosa (Fischer & Meyer) Munz). [TWISTED EVENING-PRIMROSE] "Dunes and sandy flats: above Bakers Beach...near Mountain Lake...Richmond district...Lone Mountain....Golden Gate Park...dunes, Sunset District...Lake Merced."

Oenothera elata Kunth ssp. ***hookeri*** (Torrey & A. Gray) W. Dietr & W.L. Wagner (*Oe. hookeri* Torrey & A. Gray) "...brushy slopes and moist places about Lake Merced...". Occurs today in Fort Funston dunes, particularly northeast-facing slopes with dune scrub.

NYCTAGINACEAE

Abronia latifolia Eschscholz YELLOW SAND VERBENA. "dune hills and sandy flats...Bakers Beach...Lands End...near Cliff House...dunes, Sunset...coastal dunes south of Fort Funston...". The species is based on a San Francisco collection made on the second Kotzebue expedition in 1824. A dominant species of foredunes and early phases of stable dunes. Occurs also at Ocean Beach foredunes.

Abronia umbellata Lamarck ssp. ***umbellata*** (introgressive with *A. latifolia*) PINK SAND VERBENA. "Rare on sandy beaches: Crissy Field, Presidio...Hunters Point according to Brandegee". Local light pink to salmon flowered types at Crissy Field are perennial introgressants, not typical species. Collected by Rubzoff at Ocean Beach (CAS).

PAPAVERACEAE

Eschscholzia californica Cham. CALIFORNIA POPPY. "...dune flats, grassy hills...widespread and variable: Presidio....Lone Mountain...dunes, Sunset District...". Persists at most dune remnants, including Sunset Heights.

Meconella linearis (Bentham) Nelson & MacBride. [MECONELLA]. "sandy soil of coastal hills....Lobos Creek....Mountain Lake...Lake Merced". Not recently reported; may be extirpated.

Platystemon californicus Benth. CREAM CUPS. "...dunes...San Francisco..". Not recently reported from dune remnants.

PLANTAGINACEAE

Plantago erecta E. Morris CALIFORNIA PLANTAIN. "abundant on open grassy slopes and dune flats, often in shallow soil...above Bakers Beach..dunes, Richmond district...dunes, Sunset District...Lone Mt.". Persists at Presidio dunes.

PLUMBAGINACEAE

Armeria maritima (Miller) Willd. *var.* ***californica*** (Boiss.) Pors. SEA-PINK, THRIFT. "bluffs, dunes....Point Lobos...Richmond district...Sunset Heights...dunes, Sunset district." Persists in local abundance at Sunset Heights.

POLEMONIACEAE

Gilia capitata Sims ssp. ***chamissonis*** (E. Greene) V. Grant DUNE GILIA. "common and colonial on dunes and sandy flats...near Bakers Beach...Presidio...Lone Mountain...dunes, Sunset district...". Persists at most remnant dunes.

Linanthus grandiflorus (Benth.) E. Greene LARGE-FLOWERED LINANTHUS. "open grassland; near Presidio ....(near Lake Merced)...". Occurs locally in old stable dunes at Point Reyes.

Linanthus parviflorus (Benth.). E. Greene (*L. androsaceus* (Benth.) E. Greene ssp. *croceus* (Milliken) Mason) COMMON LINANTHUS. "forming colonies in sandy soil...Presidio..Lake Merced...". Not recently reported from local dunes.

Navarretia squarrosa (Esch.) Hook. & Arn. SKUNKWEED. "common on sandy and clayey flats....Lobos Creek to Fort Point..Presidio...dunes, Sunset District; Lake Merced....". The Presidio was the type locality. Scarce in dune remnants; persists very locally behind the Marine Hospital, Presidio.

POLYGONACEAE

Chorizanthe cuspidata S. Watson. (includes var. *marginata* Goodman, not recognized) SAN FRANCISCO SPINEFLOWER. "sandy flats, slopes, and dunes...Bakers Beach, near Cliff House, Richmond...Lake Merced....". San Francisco is the type locality. Persists at most dune remnants with vegetation gaps.

Eriogonum latifolium Smith COAST BUCKWHEAT. "sandy soil...common, variable...ocean beach....dunes, Sunset". Persists at most dune remnants, locally abundant.

Polygonum paronychia Cham. & Schldl. DUNE KNOTWEED. "sandy flats and slopes...above Bakers Beach...Lone Mountain.. Sunset Heights...Ocean beach". San Francisco is the type locality. Persists widely, but sparsely, in remnant dunes. Also occurs near Cliff house, Fort Funston.

Pterostegia drymarioides Fischer & Meyer [PTEROSTEGIA] "...rarely in the open on clayey or sandy soil...". Occurs at Baker Beach dunes; probable at Fort Funston.

***Rumex maritimus* L.** *(Rumex fueginus* Phillipi*)* GOLDEN DOCK. "...dunes, Sunset district...". Likely in dune slacks with bare sand, as in Marin County.

Rumex salicifolius J.A. Weinm. **var. *crassus*** (Rech.f.) J. Howell. WILLOW DOCK. "sandy soil on slopes and flats near the ocean...Bakers Beach...Point Lobos...Ocean Beach west of Lake Merced".

PORTULACACEAE

Calandrinia ciliata (Ruiz Lopez & Pavon) de Candolle RED MAIDS. "occasional in open...sandy...". Not recently reported in local dunes. Occurs in Monterey Bay dunes, including those recently stabilized.

Claytonia perfoliata Willd. ssp. ***perfoliata*** (*Montia perfoliata* (Donn.) Howell) MINER'S LETTUCE. "dunes, Sunset district..." Also abundant at Lobos Creek and Bakers Beach dunes, particularly on moist, shaded, or northern slopes.

RANUNCULACEAE

Ranunculus californicus Benth. CALIFORNIA BUTTERCUP. "....dunes..widespread and variable....Presidio".

ROSACEAE

Acaena pinnatifida Ruiz Lopez & Pavon var. ***californica*** (Bitter) Jepson (*A. californica* Bitter) ACAENA. "Sandy....flats....Presidio; Point Lobos; Lone Mt....Sunset Heights".

Fragaria chiloensis (L.) Duchesne BEACH STRAWBERRY. "...dunes...above Bakers Beach...Lands End..near Cliff House...Lone Mt. Sunset Heights...dunes, Sunset district...Lake Merced...".

? ***Horkelia californica*** Cham. & Schindl. ssp. ***californica*** CALIFORNIA HORKELIA. "Sunset Heights" [possible in old dune scrub].

Horkelia cuneata Lindley ssp**. *cuneata*** (*Potentilla Lindleyi* Greene) WEDGE-LEAFED HORKELIA. "Sandy soil near the ocean...Ocean View and Lake Merced...". Apparently extirpated in San Francisco dunes.

Horkelia cuneata Lindley ssp**. *sericea*** (A. Gray) Keck KELLOGG'S HORKELIA. "Sand hills near the ocean: Point Lobos and Sunset Heights (acc. Brandegee)..Lake Merced...Ocean View...". Extirpated in San Francisco; nearest dune locality of this rare plant is in Daly City.

? *Oemleria cerasiformis* (Hook. & Arn.) J.W. Landon (*Osmaronia cerasiformis* Torrey & A. Gray ex Hook. & Arn.) OSO BERRY. "above Bakers Beach". Possibly present in old dune scrub.

? *Potentilla anserina* L. ssp. pacifica (Howell) Rousi SILVERWEED. "in marshy places and about seepages..". Not specifically cited for dunes or dune slacks, but almost certainly must have been at least locally common in dune slacks of the Sunset district, with *Juncus lesueurii,* as in most dune slacks of the central and north coast.

Rubus ursinus (Cham. & Shlecht.) CALIFORNIA BLACKBERRY. "...above Bakers Beach...Lobos Creek...Lone Mountain...Golden Gate Park...Lake Merced....San Francisco is the type locality.".

RHAMNACEAE

Rhamnus californica Eschscholtz COFFEE-BERRY. "dunes, Sunset district...Lone Mountain. ...Presidio....According to Dr. Behr (Zoe 2:3 - 1891) most hill tops in the western part of the city were formerly crowned by an extensive chaparral of robust plants of this species...The Presidio is the probable type locality of this species...". Also occurs at Fort Funston dunes, Sunset Heights dunes.

SALICACEAE

Salix exigua Nutt. (*S. Hindsiana* Benth.) WILLOW "...dunes of the Sunset District acc. Raven...".

Salix lasiolepis (*S. l.* var. *bigelovii* (Torrey) Bebb indistinct acc. Hickman 1993) ARROYO WILLOW. "in wet places on strands dunes....dunes, Sunset District....sandhills near Cliffhouse...Lake Merced" . Willow thickets occur in wet dune slacks (e.g. dunes of Mendocino county), streamsides, (e.g. Lobos Creek) and hillside seeps with climbing dunes (e.g. Sunset Heights). They also occur on dunes where mobile dunes override slacks (e.g. Sunset, Kaufeldt 1954; Pescadero dunes).

SCROPHULARIACEAE

Castilleja wightii Elmer (*C. latifolia* Hook. & Arn. var. *wightii* (Elmer) Zeile) WIGHT'S PAINTBRUSH. "...occasional on brushy slopes: Lake Merced....". Plants with yellow to orange bracts and strongly glandular stems below the inflorescence, common on the adjacent San Mateo coast, which are clearly referable to this species have not been recently verified in San Francisco dunes. Slightly glandular *C. affinis* occurs in San Francisco dunes, sometimes identified as *C. wightii*, but distinct from *C. wightii* of the San Mateo coast.

Castilleja affinis Hook & Arn***. ssp. affinis* (as *C. latifolia*** Hook. & Arn. in Howell *et al*. 1959) INDIAN PAINTBRUSH. "...slopes in coastal brush and grassland....above Bakers Beach...Lobos Creek to Fort Point..Point Lobos...dunes, Sunset district..Lake Merced...". Many taxonomically ambiguous plants in San Francisco are atypical for *C. affinis* ssp. *affinis*, and have some foliar characters approaching *C. latifolia*. This species is the locally common paintbrush of coastal bluff and dunes scrub south of San Francisco. San Francisco and Monterey Bay have been variously cited as the type locality of *C. latifolia*.

Castilleja exserta (A.A. Heller) Chuang & Heckard ssp***. latifolia*** (S. Watson) Chuang & Heckard. (*Orthocarpus purpurascens* Benth. var. *latifolius* S. Watson) BROADLEAF PURPLE OWL'S-CLOVER. "...Dunes and coastal grassland, often common locally: Lake Merced...near Ocean View...". Presumed extirpated here. Locally abundant in parts of San Bruno Mountain, San Mateo coast (Rockaway Head, Pacifica, on old dune soil), Point Reyes, and in older Monterey Bay dunes.

Linaria canadensis (L.) Dum.-Cours. (including *L.c.* var. *texana* (Scheele) Pennell) BLUE TOADFLAX. "...forming colonies locally in sandy places: ...near Bakers Beach...dunes, Sunset district...Lake Merced...". Found some years near Baker Beach, Lobos dunes.

Limosella aquatica L. MUDWORT. "borders of drying pools and vernally moist hollows: Presidio; Lone Mountain....in reporting the station from the Presidio, K. Brandegee (p. 367) stated, 'these pools are being filled with sand in the process of grading the tract and will soon be destroyed.'". Brandegee's comment suggests dune slack populations of *Limosella*; *L. acaulis* is present in dune slacks at Point Reyes.

Mimulus guttatus DC (*M.g.* var. *grandis* Greene) MONKEY-FLOWER. "...near Bakers Beach....Lobos Creek....dunes, Sunset district...". Almost certainly an element of the dune slack flora, as at Dillon Beach, Marin County.

Mimulus aurantiacus Curtis STICKY MONKEY-FLOWER. "common on brushy slopes: ...above Bakers Beach...Lone Mountain....dunes, Sunset District..Lake Merced...".

Scrophularia californica Cham. & Schindl. CALIFORNIA FIGWORT, BEE-PLANT. "common on brushy slopes...Lobos Creek...above Bakers Beach...dunes, Sunset district...". Also locally abundant on remnant dunes of Sunset Heights, Fort Funston.

Triphysaria pusilla (Benth.) Chuang & Heckard (*Orthocarpus pusillus* Benth.) SMALL OWL'S-CLOVER. "Rather common on grassy flats and slopes, often in shallow soil: ...near Bakers Beach...dunes, Sunset district...".

URTICACEAE

Urtica dioica L. ssp. ***holosericea*** (Nutt.) Thorne (*U. holosericea* Nutt.) HOARY NETTLE. "in sandy soil among oaks...Golden Gate Park". This species also occurs in local abundance at the margins of dune slacks with organically rich soils.

VIOLACEAE

? ***Viola adunca*** Smith. WESTERN DOG VIOLET. "open grassy hills...Bakers Beach...Sunset Heights...".

Monocots (grasslike plants, lily-like plants)

CYPERACEAE

Carex obnupta L. Bailey. SLOUGH SEDGE. "wet places among coastal hills and dunes...Lobos Creek, Golden Gate Park...Lake Merced". Also known in wet dune slacks at Point Reyes, Marin County.

(?) ***Carex pansa*** L. Bailey. [SAND SEDGE]. Uncertain status in San Francisco dune flora, from a single questionable record that may have been confused with a Pacific Grove locality. Known from dunes in Monterey and San Luis Obispo Counties.

Eleocharis macrostachya Britton SPIKERUSH. "Golden Gate Park...". Likely in dune slacks. Found in dune slacks of Point Reyes, Marin County.

(?) ***Scirpus cernuus*** Vahl. [SEEP SEDGE] "wet soil of marshes, strands, and seepages". Likely in seasonally ponded or saturated dune slacks.

(?) ***Scirpus californicus*** (C. Meyer) Steudel CALIFORNIA TULE. "Golden Gate Park" (likely component of original wet dune slacks and "Presidio Swamp").

Scirpus pungens Vahl. (*S. americanus* Persoon) COMMON THREESQUARE.   "...Golden Gate Park...Lake Merced". Probable in dune slacks or seasonal streams in dunes, especially early colonization of saturated sand. Found abundantly in dune slacks of Dillon Beach, Marin County.

JUNCACEAE

Juncus bufonius L. TOAD RUSH. "common and widespread in moist or wet soil". Likely in seasonally ponded dune slacks, as in central and north coast dune slacks; several likely dune localities are cited in Howell *et al*. 1958.

Juncus lesueurii Bolander. [SALT MARSH RUSH] "wet places on slopes and flats, sometimes bordering salt marshes" Presidio...Lone Mountain Golden Gate Park". This species, and the questionably distinct ***J. breweri*** Engelm. and their intermediate forms (not recognized by Howell *et al*. 1958), are commonly found in dunes and dune slacks of Marin County.

Juncus phaeocephalus Engelm. BROWN-HEADED RUSH. "Wet soil of sandy flats or marshy places, rather common: ....Lone Mountain....Lake Merced...". Likely in dune slacks, as at Point Reyes and Dillon Beach, Marin County.

LILIACEAE

Triteleia laxa Abrams (*Brodiaea laxa* (Bentham) Watson) ITHURIEL'S SPEAR. "dunes in Sunset District".

POACEAE

(?) ***Agrostis pallens*** Trin. (*A. diegoensis* Vasey). THIN BENT, DUNE BENT. Described as "common on open or brushy slopes" by Howell *et al*. (1958), but not explicitly cited from dunes. In Marin and Sonoma Counties, this species is commonly found on stable dunes (Howell 1949, Best *et al.* 1996), and its occurrence on San Francisco dunes was likely.

Bromus carinatus Hook. & Arn. **var. *carinatus*** CALIFORNIA BROME. "dunes, Sunset District".

Bromus carinatus Hook. & Arn. **var. *maritimus*** Piper) C. Hitchc. (*B. maritimus* (Piper) Hitchcock) [MARITIME BROME]. "Forming clumps among coastal dunes and on sandy hills...Presidio...Point Lobos...Lone Mountain...Sunset Heights...dunes, Sunset District...Lake Merced".

Leymus mollis (Trin.) Pilger ssp. ***mollis*** (*Elymus mollis* Trin.) PACIFIC DUNEGRASS, SEA-RYE. "Dunes along the ocean shore: near cliff house". Modern populations occur at Crissy Field beach (dwarfish strains), Sutro baths slopes, Ocean Beach near Irving St., Ortega to Riviera Streets, and at the north end of Fort Funston dunes.

Leymus pacificus (Gould) E.R. Dewey. [PACIFIC WILDRYE] "Dunes and sandy flats, where rather frequent... Bakers Beach... Presidio... Sutro Heights...above point Lobos, Richmond distric....Golden Gate Park...". Also at Fort Funston, dune slope above Balboa at Great Highway. Some plants intermediate with *L. triticoides* in some characters.

Leymus* x *vancouveriensis (Vasey) [VANCOUVER WILDRYE, HYBRID DUNEGRASS] "sandy hollow east of Lake Merced". Extirpated; proposed for reintroduction at Crissy Field dunes, 1999.

Festuca rubra L. RED FESCUE. "forming patches locally on ...dunes and coastal bluffs....above Bakers Beach... Point Lobos... Lone Mountain....".

Melica imperfecta Trin. MELIC-GRASS. "sandy flats, dunes...Point Lobos, Sunset...Lake Merced". Also above Baker Beach.

Phalaris californica Hook. & Arn. [CALIFORNIA CANARY-GRASS]. "along streams in the sand hills and coastal bluffs: Point Lobos...Laurel Hill cemetery...". Probably extirpated in dunes here.

Poa douglasii Nees. DUNE BLUEGRASS. "Occasionally forming colonies on dunes and sandy flats: 'sand near the sea....Point Lobos, Richmond district, Sunset district, Lone Mountain.". Occurs today at Baker Beach, Fort Funston, Sunset Heights, dunes above Balboa and Great Highway.

Poa unilateralis Vasey. OCEAN-BLUFF BLUEGRASS. "dunes, Sunset district." Possibly extirpated on dunes.

Vulpia microstachys (Nutt.) Benth. var. ***microstachys*** (*Festuca megalura* Nutt.) [ANNUAL FESCUE] "common on...dunes...near Bakers Beach...Presidio...dunes, Sunset District".

Vulpia octoflora var. ***hirtella*** (Walter) Rydb. (*Festuca octoflora* var. *hirtella* Piper) [ANNUAL FESCUE] "sandy slopes above Bakers Beach...".

TYPHACEAE

Typha dominguensis Pers. SOUTHERN CATTAIL. "wet and marshy places...dunes, Sunset district". This collection undoubtedly refers to perennially moist dune slack.

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APPENDIX II
Native Vascular Plant Species of Serpentine Outcrops of the Northern San Francisco Peninsula

The following list of vascular plants occurring on serpentine outcrops in San Francisco is compiled from Howell *et al.* 1958 and McCarten 1986, based on explicit references to species growing on serpentine soils. Species included parenthetically [ ] indicate either author's observations, or species that are not explicitly cited by Howell *et al*. (1958) as occurring on serpentine (e.g. some species recorded at Bayview Hills), but are interpreted as likely occurrences on serpentine due to generally observed affinity for serpentine sites, and occurrence at localities with known serpentine inclusions (and other records of typical serpentine species). The "serpentine" of botanists may include greenstone (identified as KJg on U.S. Geologic Survey maps of San Francisco), volcanic rocks that sometimes resemble the grayish blue-green serpentine rocks, but have less extreme forms of the distinctive chemistry of serpentine. Serpentine occurrences are indicated in U.S.G.S. maps as "sp" and "sph"; they may occur as inclusions in "Ks" (sheared rocks).

Nomenclature follows Hickman 1993, with synonymy provided from Howell *et al.* 1958. English names are compiled from primarily Best *et al*. 1996 and Hickman 1993. English names given in brackets are artificial English translations provided when conventional common names are lacking.

The list does not cover mosses and lichens, which may occur in local abundance on bedrock outcrops. Species marked with an asterisk * are reported to occur often on serpentine, at least in the San Francisco flora. Parenthetic question marks (?) indicate either some degree of taxonomic uncertainty, or less certainty of occurrence on serpentine. Historic collection localities that include references to serpentine soils include Potrero Hills, Laurel Hill, Masonic Cemetery, Presidio, and Hunters Point.

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- Pteridophytes -
(Ferns and fern-like plants)

Polypodiaceae

Polypodium californicum
CALIFORNIA POLYPODY FERN
Polypodium scouleri
LEATHERY POLYPODY FERN
Pteridium aqualinum
BRACKEN FERN
Pityogrammma triangularis
GOLDBACK FERN

- Angiosperms or Anthophytes -
(Flowering plants)

DICOTS
(broad-leaf flowering plants)

Apiaceae

Daucus pusillus
RATTLESNAKE WEED
Lomatium caruifolium var. *caruifolium*
[CARAWAY-LEAF LOMATIUM]
Lomatium dasycarpum ssp. *dasycarpum**
[LOMATIUM]
*Perideridia kelloggii**
[KELLOGG'S SQUAWROOT]
Sanicula arctopoides
YELLOW MATS
*Sanicula bipinnatifida**
PURPLE SANICLE

Asteraceae

Achillea millefolium
YARROW
Agoseris apargioides
COAST DANDELION
Artemisia californica
CALIFORNIA SAGEBRUSH
[Aster chilensis]
[CHILEAN ASTER]
Baccharis pilularis
COYOTE-BRUSH
Cirsium andrewsii
FRANCISCAN THISTLE
Cirsium quercetorum
BROWNIE THISTLE
Erigeron glaucus
SEASIDE DAISY
[Eriophyllum staechadifolium]
LIZARD-TAIL
Filago californica
[CALIFORNIA FILAGO]
Gnaphalium microcephalum
[SMALL-HEADED CUDWEED]
Gnaphalium purpureum
[PURPLE CUDWEED]
Grindelia hirsutula var. maritima (G. maritIma)
SAN FRANCISCO GUMPLANT
Hesperevax sparsiflora (Evax sparsiflora)
[FEW-FLOWERED EVAX]
[Helianthella castanea]
DIABLO HELIANTHELLA
Lasthenia californica (Baeria chrysostoma)
CALIFORNIA GOLDFIELDS
Layia platyglossa
TIDY-TIPS
Lessingia filaginifolia var. *californica*
CALIFORNIA-ASTER
Microseris bigelovii
[BIGELOW'S MICROSERIS]
Microseris douglasii
[DOUGLAS' MICROSERIS]
Psilocarphus tenellus
WOOLY-MARBLES
Solidago spathulata
COAST GOLDENROD
[Wyethia angustifolia] (?)
MULE-EARS
Uropappus linearifolius (Microseris linearifolia)
SILVER-PUFFS

Boraginaceae

[Cryptantha flaccida]
CRYPTANTHA
(?) *Plagiobothrys reticulatus* var. *rossorianum* (*P. diffusus*)
GREENE'S POPCORNFLOWER**

Brassicaceae

[Arabis blepharophylla]
COAST ROCKCRESS
Lepidium nitidum
SHINING PEPPERCRESS

Caryophyllaceae

Spergularia macrotheca
STICKY SAND-SPURREY
Minuartina pusilla
[LITTLE SANDWORT]

Convolvulaceae

[Calystegia purpurata ssp. *purpurata](Convolvulus occidentalis* var. *purpuratus)*
MORNING-GLORY
Calystegia subacaulis
HILL MORNING-GLORY

Crassulaceae

Dudleya farinosa
[COAST DUDLEYA]

Ericaceae

Arctostaphylos hookeri ssp. *franciscana** *(A. franciscana)*
FRANCISCAN MANZANITA
Arctostaphylos hookeri ssp. *ravenii** *(A. franciscana* misappl.)
RAVEN'S MANZANITA

Fabaceae

*Astragalus gambellianus**
GAMBELL'S MILKVETCH
Lotus wrangelianus (L. subpinnatus)
CALF LOTUS
Lupinus nanus
[DWARF LUPINE]
Lupinus variicolor
[COAST LUPINE]
Lupinus bicolor`
MINIATURE LUPINE
Trifolium depauperatum var. *amplectens (T. amplectens*)
PUFFY CLOVER, BLADDER CLOVER
Trifolium fucatum (T. flavum)
BULL CLOVER
Trifolium gracilentum var. *gracilentum*
PINPOINT CLOVER
Trifolium macraei
CHILE CLOVER
Trifolium microdon
SQUARE-HEAD CLOVER

Trifolium microcephalum
MAIDEN CLOVER

Gentianaceae

Centaurium muehlenbergii
CANCHALAGUA

Hydrophyllaceae

Phacelia californica
[CALIFORNIA PHACELIA]

Lamiaceae

Stachys ajugoides var. *rigida (S. rigida* ssp. *quercetorum)*
HEDGE-NETTLE

Linaceae

[Hesperolinon californicum]
[CALIFORNIA DWARF-FLAX]
*Hesperolinon congestum**
MARIN DWARF-FLAX

Onagraceae

*Clarkia franciscana**
PRESIDIO CLARKIA

Orobanchaceae

[Orobanche californica ssp. *californica*]
CALIFORNIA BROOM-RAPE
Orobanche fasciculata
CLUSTERED BROOM-RAPE

Papaveraceae

Eschscholzia californica
CALIFORNIA POPPY
Platystemon californicus
CREAM-CUPS

Plantaginaceae

Plantago erecta
[ERECT PLANTAIN]
[Plantago maritima]
SEASIDE PLANTAIN

Plumbaginaceae

[Armeria maritima ssp. *californica]*
CALIFORNIA SEA-PINK

Polemoniaceae

Gilia clivorum
GILIA

Polygonaceae

Eriogonum latifolium
COAST BUCKWHEAT
Eriogonum nudum (?)
NUDE BUCKWHEAT
Pterostegia drymarioides
PTEROSTEGIA

Portulacaceae

Calandrinia ciliata
RED MAIDS
Claytonia exigua ssp. *exigua (Montia spathulata)*
CLAYTONIA
Claytonia perfoliata
MINER'S-LETTUCE

Ranunculaceae

Ranunculus californicus
CALIFORNIA BUTTERCUP

Rhamnaceae

Ceanothus thyrsiflorus
BLUE-BLOSSOM

Rosaceae

Aphanes occidentalis (Alchemilla occidentalis)
WESTERN LADY'S MANTLE
[Fragaria chiloensis]
BEACH STRAWBERRY
[Oemleria cerasiformis]
OSO BERRY
[Heteromeles arbutifolia]
TOYON

Rubiaceae

Galium porrigens (G. nuttallii misappl.)
CLIMBING BEDSTRAW

Scrophulariaceae

Castilleja affinis ssp. *affinis*
COAST INDIAN-PAINTBRUSH
Castilleja subinclusa ssp. *franciscana (C. franciscana*)
FRANCISCAN INDIAN-PAINTBRUSH
Collinsia multicolor (C. franciscana)
FRANCISCAN CHINESE-HOUSES
[Mimulus aurantiacus]
STICKY MONKEYFLOWER
Mimulus guttatus
LARGE MONKEYFLOWER
*Triphysaria floribunda (Orthocarpus floribundus)**
SAN FRANCISCO OWL'S-CLOVER
Scrophularia californica
BEE-PLANT

Violaceae

Viola pedunculata
WILD PANSY

- MONOCOTS -
(Flowering plants with single seedling-leaves or cotyledons)

Cyperaceae

Carex densa
DENSE SEDGE
Carex gracilior
SLENDER SEDGE

Juncaceae

Juncus bufonius
TOAD RUSH
[J. occidentalis]
[WESTERN RUSH]

Iridaceae

[Iris douglasiana]
DOUGLAS IRIS
[Sisyrinchium bellum]
BLUE-EYED GRASS

Liliaceae

Allium dichlamydium
COAST WILD ONION
Brodiaea terrestris ssp. *terrestris*
GROUND BRODIAEA
Chlorogalum pomeridianum
SOAP-PLANT
Dichelostemma capitatum (Brodiaea pulchella)
BLUE-DICKS
Muilla maritima
MUILLA
Tritelia laxa (Brodiaea laxa)
ITHURIEL'S SPEAR
Zigadenus fremontii
STAR-LILY

Poaceae

Agrostis exarata
SPIKE BENT-GRASS
Agrostis pallens (A. diegoensis)
THIN BENT, DUNE BENT
Agrostis microphylla
[SMALL-LEAF BENT-GRASS]
Bromus carinatus var. carinatus
CALIFORNIA BROME
Danthonia californica
CALIFORNIA OATGRASS
Deschampsia cespitosa ssp. holciformis
PACIFIC HAIRGRASS
Deschampsia danthonioides
ANNUAL HAIRGRASS
Elymus glaucus ssp. *virescens (Elymus virescens)*
[GREEN WILDRYE]
[Elymus glaucus ssp. *glaucus]*
BLUE WILDRYE
Festuca idahoensis
IDAHO FESCUE, BLUE BUNCHGRASS
[Festuca rubra]
RED FESCUE
Hordeum brachyantherum
MEADOW BARLEY
Hordeum jubatum (Sitanion jubatum)
SQUIRRELTAIL BARLEY
Koehleria macrantha (K. gracilis)
JUNEGRASS
Vulpia microstachys var. *pauciflora (Festuca reflexa, F. pacifica)*
[PACIFIC FESCUE]
Melica californica
CALIFORNIA MELIC
*Melica torreyana**
TORREY'S MELIC
*Nasella pulchra (Stipa pulchra)**
PURPLE NEEDLEGRASS
Poa secunda ssp. *secunda (P. scabrella)*
PACIFIC BLUEGRASS
Poa unilateralis
OCEAN-BLUFF BLUEGRASS

****** Appears on McCarten's list of Presidio serpentine species. No reference to occurrence in serpentine in Howell *et al*. 1958, or implicit in collection locality.

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APPENDIX III
Invasive Nonnative Plants That May Affect Recovery of San Francisco Lessingia and Raven's Manzanita

Conicosia pugioniformis (L.) N.E. Br. [YELLOW ICE-PLANT]. This species is a short-lived succulent perennial herb with a single tough taproot and prostrate branches that spread radially up to several feet. Unlike iceplant (*Carpobrotus edulis* and hybrids), this species does not spread clonally by rooting prostrate stems of indefinite growth. This species spreads readily by seed in coastal dunes, and is becoming aggressively invasive around Baker Beach and Lobos dunes. It is native to South Africa, but is invasive in numerous dunes systems of the central California coast.

Carpobrotus edulis (L.) N.E. Br. and hybrids with *Carpobrotus chilensis* (L.) N.E. Br. ICEPLANT, HOTTENTOT-FIG. This species is the familiar iceplant of roadside plantings, a creeping soft-wooded succulent shrub capable of indefinite lateral clonal spread. Stems can root in contact with moist soil or sand. *Carpobrotus edulis* also spreads efficiently by seed dispersed by birds and mammals (D'Antonio 1990). Intermediate hybrids and introgressants with the less aggressive *Carpobrotus chilense* are common (Albert *et al*. 1997, Gallagher *et al*. 1997). It is a dominant species on coastal dunes and sandy bluffs, covering tens of acres of Fort Funston dunes in nearly pure stands. Iceplant also occurs in the Presidio, where it covers both serpentine and weak sandstone bluffs. Iceplant is shade-tolerant enough to form an understory beneath conifers and eucalypts planted on remnant dunes of the Presidio. This native of South Africa can be effectively removed by labor-intensive manual methods. The herbicide glyphosate is highly effective at eradicating it.

Cortaderia jubata (Lemoine) Stapf JUBATA GRASS, PAMPAS GRASS. The familiar huge plumed fruiting culms of this large (to 3 meters or more) tussock-forming grass are among the dominant features of coastal vegetation along the central coast. This highly invasive species is distinguished from the ornamental pampas grass (*Cortaderia selloana*) by the hairy sheaths on its flowering culms. It is tolerant of most serpentine soils, as well as other Franciscan rocks, marine terrace deposits, and sandstones. Jubata grass rapidly invades disturbed soils of slumps on coastal bluffs of the Presidio, particularly where seeps occur. It is native to western montane South America. This highly persistent invasive species is most easily controlled only at the seedling/juvenile stage. Removal of mature tussocks by manual methods is effective, but labor-intensive. It can also be controlled effectively by the herbicide glyphosate, but only if coverage is thorough, since individual shoots that are not exposed can regenerate independently of the parent plant.

Bromus diandrus Roth RIPGUT BROME. This species and the Mediterranean annual bromegrass *B. hordeaceus* readily invade coastal grassland, especially older dunes with incipient soil development. It is particularly invasive in *Lessingia germanorum* colonies in the Presidio. Other invasive annual exotic grasses include *Avena fatua* (wild oat), and *Briza* spp. (*Briza minor, Brizqamaxima;* rattlesnake-grasses). They can be controlled by labor-intensive manual removal, but they reinvade readily unless extensive areas are cleared completely for multiple years. In managed natural areas with infrequent native grasses, they can be controlled with grass-specific herbicides.

Cupressus macrocarpa Gordon   MONTEREY CYPRESS. This ornamental conifer is a native tree of the Monterey peninsula. It was extensively planted in San Francisco, where it has naturalized on coastal bluffs. Large groves cover remnant dunes at the Presidio and Fort Funston. It is also tolerant of many serpentine soils. It regenerates from seed and invades coastal scrub vegetation on the San Francisco peninsula, creating a dense shaded understory and thick acidic leaf litter layer.

Ehrharta erecta Lam. UPRIGHT VELDTGRASS. This South African perennial grass is a relatively recent invader. It has a tufted to mat-forming growth habit, and forms an extremely tough sod. It is particularly invasive in bedrock crevices and sidewalk cracks. It invades exposed stable coastal dunes in full sun, but is most abundant and dominant on dunes shaded by Monterey cypress, and on relatively mesic north slopes. It spreads aggressively by seed over relatively long distances, and spreads locally also by clonal growth. Upright veldtgrass is locally abundant in parts of the Presidio, Sunset, and Richmond districts of San Francisco, and is established on southwest Farallon Island (San Francisco).   Tenacious fibrous roots make manual removed very difficult. It is likely to spread throughout bedrock and dune habitats throughout San Francisco and other parts of the coast. It is sensitive to the herbicide glyphosate.

Eucalyptus globulus Labill. BLUE GUM. This large evergreen Australian tree was planted extensively on San Francisco dunes as well as on other substrates. It resprouts readily after cutting. Its evergreen leaves are resistant to decomposition and produce thick leaf litter that inhibits seedling regeneration of many native plant species. Seedlings establish spontaneously almost wherever mature trees occur in San Francisco.

Genista monspessulana (L.) L. Johnson. FRENCH BROOM. This evergreen, drought-tolerant, nitrogen-fixing shrub with sweetly scented and showy yellow flowers has spread from cultivation. It produces copious seeds, which can persist for many years in the soil. Broom aggressively invades excavated banks, landslides, artificial fill, and rocky open slopes; it seldom is invasive on dune sand. It regenerates readily from seed and from resprouts of trunks. Manual removal is difficult, and seedlings regenerate cleared stands for years after mature plants have been removed.

Pinus radiata D. Don MONTEREY PINE. Like Monterey cypress, this ornamental conifer is a native tree of the Monterey peninsula. It is particularly well adapted to sandy soils, but also colonizes serpentine coastal bluffs, spreading by seed readily. Large groves were also planted in the Presidio on relict dunes because of their tolerance to wind and salt spray. Plants do not resprout after cutting.

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APPENDIX IV
Glossary of Technical Terms

achene: a seed-like hard-coated fruit containing one seed, and functioning as one seed.

backcross: sexual reproduction between a hybrid organism and an individual from one of its parent populations.

basal rosette: a plant growth form or stage with an unelongated stem near ground level, and with a spiral circle of leaves.

blowout: a wind-eroded, mobile, mostly unvegetated portion of a dune, often forming a depression.

CAS: abbreviation for herbarium specimens of the California Academy of Sciences, Golden Gate Park, San Francisco.

Colma formation, Colma deposits: ancient deposits of mostly fine sand, variably cemented, from “fossil” lagoon and dune environments; now found well above modern sea level elevations both on the coast and inland along the northern San Francisco peninsula, resembling yellowish modern dune sand.

colonize, colonization: establishment of a species’ local population or colony in a given area.

competition: in plants, the interference with growth or reproduction in one plant that is related to the exploitation or capture of needed resources (such as light, water, space, nutrients, pollinators, shelter) by another plant.

DS: abbreviation for herbarium specimens of the Dudley/Stanford collection, housed at the California Academy of Sciences, San Francisco.

decumbent: growth habit with stems nearly prostrate, but ascending near tips.

disturbance: in the context of plant ecology, physical displacement of substrate or physical removal of biomass in a given area.

dune, dune sheet: an unconsolidated deposit of wind-blown sand in modern environments. A dune sheet is the mantle of sand covering underlying substrate formed by a wide, continuous deposit of dunes.

endemic: narrowly and uniquely restricted to a single geographic area.

eolian: related to or caused by wind, such as erosion or deposition.

extirpate: killing of a population; local extinction.

facultative: an organism that does not require, but often behaves, tolerates or thrives in, a particular condition or relationship, such as a facultative parasite (does not require a host, but readily can behave as a parasite) or facultative salt-tolerant plant (does not require salt, but can adapt to saline conditions).

fetch: the reach of open area across which wind may blow without obstruction.

floret: a small component flower within a larger structure resembling a single blossom that is a composite of many small florets.

forb: an herbaceous plant.

founder(s): the pioneering individual or individuals that colonize a new site or establish a new population; earliest ancestors of a distinct population.

Golden Gate National Recreation Area: a unit of the National Park Service, U.S. Department of the Interior, located between Tomales Bay, Marin County, and north coastal San Mateo County.

greenstone: with serpentine, mafic and ultramafic igneous rocks, derived from altered minerals of deep magmas rich in heavy metals.

Holocene: a geological epoch dating back from modern times to the end of the Pleistocene epoch when the last glaciers of the continent retreated and sea level rose rapidly, about 13,000 years ago.

hybrid: the progeny of sexual reproduction between organisms from distinct and separate lineages, such as different species, varieties, forms, or populations.

inbreeding, inbred: sexual reproduction between closely related individuals.

interspecific: between species (such as interspecific competition, interspecific hybridization, interspecific differences).

introgression, introgressant: The result of backcrossing hybrid individuals to a parent population, such that hybrids are assimilated, and their descendants fall largely within the range of variation of the one ancestral parent population; such individuals are called introgressants.

invasive: pertaining to species that rapidly establish large populations, becoming dominant, often displacing pre-existing species; “aggressive” or “weedy” species.

involucre: a structure on flower heads composed of numerous scale-like or leaf-like appendages (bracts) united to enclose unexpanded flower heads in bud-like coverings.

Merced: Ancient (Pleistocene) deposits of shallow marine or lagoon sediments ranging from clay to sand, mostly along the modern coastline and raised above modern sea level; named after the type locality at Lake Merced (Fort Funston) bluffs.

moist-chilling: a horticultural treatment of seeds to stimulate germination; moist, imbibed seed are held at very cool above-freezing temperatures for many weeks; “stratification” is an older term.

nonnative: exotic, or not indigenous to an area; introduced artificially or very recently established without precedent in ecological time-scales.

outcross: opposite of inbreeding; sexual reproduction between individuals within a species but from different lineages (families).

phyllary: a type of bract (see bract, above) in flower heads of aster (daisy) family species.

Pleistocene: a geologic epoch characterized by many cycles of glaciation (advance and retreat of continental glaciers, or ice-ages) and corresponding rise and fall of sea-level; ended with the last glaciation and the beginning of the Holocene.

serpentine, serpentinite: mineral composition extremely deficient in key plant nutrients such as calcium and magnesium, and rich in potentially toxic metals such as cadmium, manganese, and nickel. Serpentinite is the rock itself.

slack: a relatively flat, low area within a dune system where surface elevations are close to the permanent water table, and support either dune wetlands or wetland ecotones.

soil seed bank: a population of dormant seed in the soil, functioning as a pool or reservoir from which seedlings may be recruited. “Seed bank” is often used in ecological contexts without the qualifying term “soil”. In plant conservation contexts, the terms “banked seed” or “seed banks”, in contrast, refer to artificially stored seed.

succession: a developmental pathway of ecological change, typically involving shifts in vegetation composition and structure as well as soil change; partly analogous with orderly development of individual organisms, but more indeterminate and affected by circumstantial or chance factors.

taxon (singular), **taxa** (plural): any unit of biological classification, such as variety, subspecies, species, genus, etc.

UC: abbreviation for herbarium specimens from the University of California (Berkeley).